LEXICAL AND SANDHI TONES IN NANCHANG GAN: A PHONETIC DESCRIPTION

Yu Cai

A thesis submitted to the faculty at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Arts in the Department of Linguistics

Chapel Hill
2021

Approved by:

Jennifer L. Smith

David Mora-Marin

Elliott Moreton

ABSTRACT

Yu Cai: Lexical and Sandhi Tones in Nanchang Gan: A Phonetic Description
(Under the direction of Jennifer L. Smith)

This study is a descriptive and quantitative analysis of tones in Nanchang Gan (NCG). The broader goal of this project is to contribute to the preservation of NCG, and tones in this language serve as a starting point. Specifically, this study looks at tones on monosyllabic words and tones on the first word of disyllabic compounds in NCG, as well as tone sandhi patterns in this language. Quantitative analyses were conducted, and the results show that there are five monosyllabic tones and eight disyllabic-compound-initial tones in NCG. Moreover, by comparing the tones of morphemes when produced in the monosyllabic and disyllabic contexts, nine tone sandhi patterns were found, some of which appear to parallel Mandarin tone sandhi patterns.

Keywords: Nanchang Gan, tone, Chinese phonology, phonetics, language documentation, tone sandhi, acoustics

ACKNOWLEDGEMENTS

I would like to express my gratitude to the members of my committee, Jennifer Smith, Elliott Moreton and David Mora-Marin. First and foremost, I would like to give special thanks to my thesis advisor, Jennifer Smith, for her guidance, expertise, and openness which continually facilitated the progress of my work throughout my studies. Without her insightful comments, this project would not have been realized. I would also like to thank the rest of the committee members, Elliott Moreton, and David Mora-Marin, for their insightful thoughts, suggestions, and encouragement to pursue this topic further. The Linguistics Department at UNC is truly appreciated.

I would also like to thank Chris Wiesen as my statistics expert from the Odum Institute, thank him for helping me with doing the statistical analysis, without which my thesis would be impossible to complete.

Special thanks to my all family, especially Xinyuan Guan for giving me emotional support along the way, always encouraging me to never lose hope and cheer up. The support from all of my friends during this time is highly appreciated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1. Research Questions

For my thesis project, I looked at tones in a Chinese language-Nanchang Gan. Specifically, I am interested in the following questions: a) what monosyllabic lexical tones exist in Nanchang Gan (NCG) – comparing with the previous findings, how many tones were found in this project? how to categorize them on the phonetic level? b) what tones exist on the first syllable of disyllabic compounds? c) what tone sandhi (TS) patterns can be observed by putting monosyllabic tones into disyllabic words (especially looking at tone sandhi on the initial syllable).

Tone is a pitch that conveys part of the meaning of a word; pitch variations that affect the meaning of a word. Languages that use tones to distinguish words or their inflections, analogously to consonants and vowels are called tonal languages (Trask, 2004). Tonal languages are often seen in East and Southeast Asia, the Pacific, Africa, and the Americas. Among them, Chinese languages are among the most well-known tonal languages used today (Yip, 2002).

Tone sandhi is a phenomenon in which the tones assigned to individual words or morphemes change based on the pronunciation of adjacent words or morphemes (Yip, 2002). In this study, I am interested in the TS pattern on the initial syllable of the disyllabic word, this is mainly based on my observation and assumption of the prosodic directionality of this language (more details in *2.3*): NGC is both geographically-close and phonetically similar to the right-dominant Chinese languages, which means in a disyllabic word, the tone on the second syllable remains unchanged,

while the initial one undergoes TS. The behaviors of both syllables were checked to reconfirm the assumption in the project analysis.

Yuan (1989) and Liu (2010) both investigated tones in NCG in which Yuan (1989) first reported NCG among a large diversity of Chinese languages. Yuan (1989) briefly mentioned NCG as a member in Gan languages, and that it is a language having five lexical tones: high falling tone, high rising tone, falling rising tone, low rising tone, and high tone. Liu (2010) has also investigated tonal inventories with different rhyme durations in NCG and proposed five lexical tones in NCG: mid falling, low rising, high, falling rising, and low falling tone. The auditory judgment of me as a native speaker (the only participant in this research) aligns with the previous claim of Yuan (1989). Thus, in my research, I am expected to find the results confirming the previous proposal.

Two sets of quantitative analyses, one for the tones on the monosyllabic words the other for the tones on the first syllable disyllabic of disyllabic compounds, were conducted. Visual inspections made via graphs as well as statistical analyses were presented. Based on the results, I, therefore, propose that there are five monosyllabic tones in NCG, and they should be categorized as mid tone, falling rising tone, low rising tone, high rising tone, and mid falling tone, which were different from what the previous studies (Liu (2001) & Yuan (1989)) proposed. Regarding the disyllabic tones, there are in total eight tones when appearing on the first syllable of disyllabic compounds: mid tone, low rising tone, high tone, low tone, low falling tone, (new) mid falling tone, mid rising tone and a relatively complicated tone 8. Nine tone sandhi patterns can be observed from the data among which mid tone and low rising tone are the most popular tones

after tone sandhi, and some of the tone sandhi patterns show correspondingly support from Mandarin tone sandhi.

1.2. NCG in Nanchang

When travelling across Jiangxi province (or Gan) in southeastern China, one is expected to encounter various languages, differing from village to village, town to town. These languages belong to Gan Chinese.

FIGURE 1: Chinese language groups[1]

Gan Chinese belongs to the Sino-Tibetan language family. As one of the eight major dialects & languages in China, it has 22 million speakers who come from Jiangxi, as well as some speakers from the surrounding regions such as Hunan, Hubei, Anhui, and Fujian. As pointed out by Wurm et al. (1988) in Language Atlas of China, there are nine major languages within Gan Chinese, and among them, Nanchang Gan (NCG) is the best-known one

[1] Based on Language Atlas of China, by Stephen Adolphe Wurm, Rong Li, Theo Baumann and Mei W. Lee, Longman, 1987, ISBN 978-962-359-085-3.

Nanchang Gan, also known as Chang-Du or Chang-Jing, is named after the city Nanchang and the county of Chang du. Besides being spoken mainly in Nanchang, it also spreads over into the areas including Xinjian, Anyi, Yongxiu, De'an, Xingzi, Hukou, and some bordering regions in Jiangxi and Pingjiang County, Hunan. The emergence of Nanchang Gan is the result of population immigrations after Qin & Han Dynasties about 2000 years ago. Before that, the Jiangxi area was under the dominance of different states at different times, and the languages people spoke were either the ancient Chu or ancient Yue. After the immigration at the end of the Qin & Han Dynasties, people living in this area started to form a new language based on ancient Chu & Yue, and that was when NCG came onto the stage. The city of Nanchang was officially built at the end of the Han Dynasty, which helped to stabilize as well as facilitate the development of NCG.

Since Mandarin was appointed as the official language of China by the establishment of the People's Republic of China in 1949, and later on the government order the "promotion of Mandarin" in 1956, young generations have less chance to get in touch with their local languages. Mandarin is the language used at school, work and all the other official events, while people only have a chance to practice their local tongue in informal situations such as at home or grocery stories. The same story happens to NCG, since the end of the last century, young generations gradually abandoned NCG under the "promotion of Mandarin". Moreover, people looked down on this language as Nanchang has been showing a slow economic development comparing to other capital cities in China, which made young people more reluctant to learn NCG. Hence, the lack of thorough documentation of this language made it necessary to fully document at least some aspects of this language.

1.3. Scope of the Study

This thesis constitutes the phonetic description of the tones of a Chinese language: Nanchang Gan. It is possibly the first quantitative study of the language, focusing mainly on the phonetic properties of its tones. It looks to identify tone categories and comparing them to the previous findings in Yuan (1989) and Liu (2010). To investigate the monosyllabic lexical tones and the tone sandhi when those are put into disyllabic words (here only focusing on the initial syllable), analysis for the monosyllabic tones, and analysis for the tones in disyllabic words are both performed on this language. Chapter two sets up the background for the study by briefly introducing the phonology of this language, and some key terms that are relevant to the current study. Chapters three and four each focuses on one analysis, within which the methodology (including the stimulus, the participant, the data collection, the data analysis, and the statistical analysis), results, and the relevant discussion session are provided. Lastly, in chapter five conclusions are drawn about tones in NCG, and points for future research are discussed.

CHAPTER 2: BACKGROUND

Over the decades, tone languages have been a hot spot of discussion. Taking the advantage of the already-rich academic resources/background, I am able to find lots of inspirations that my project can connect to, as well as follow the theoretical system that is appropriate based on my current judgment.

In the following sections, I am going to presents the relevant ideas and studies to understand what each factor can contribute to analyzing the phenomenon of tones in NCG. Specifically, I will start by talking briefly about the phonology of NCG, tone bearing unit of NCG, the directional prosodic system of NCG, and the morphological form of the data in this study.

2.1. Nanchang Gan Phonology

According to Yan (2006), there are 8 vowels and 19 consonants in NCG. Table 1 and 2 are shown a summary of the proposed phonemes:

TABLE 1: Vowel phonemes of NCG (Yan 2006)

	Front	Central	Back
High	i y		u
Mid	ɛ	ə	o ɔ
Low		a	

TABLE 2: Consonant phonemes of NCG (Yan 2006)

		Bilabial	Dental/alveolar	(Alveolo-) palatal	Velar	Glottal
Nasal		m	n	ɲ	ŋ	
Stop	plain	p	t		k	
	aspirated	p^h	t^h		k^h	
Affricate	plain		ts	tɕ		
	aspirated		ts^h	$tɕ^h$		
Fricative		ɸ	s	ɕ		h
Lateral			l			

Based on my data, there are two syllable types in NCG: CV (C = consonant; V = vowel); CVN (N = nasal); and there is no vowel length contrast in Nanchang.

Yuan (1989) first reported that there are five lexical tones in NCG: high falling, high rising, falling rising, low rising, and high. Liu (2010) has also investigated tonal inventories with different rhyme durations in NCG and proposed five lexical tones in NCG: mid falling, low rising, high, falling rising and low falling (or as been transcribed in the paper in a five-point scale as 42, 24, 45, 213, and 21). In addition to that, the author proposed a different syllable structure in NCG which includes CV (C = Consonant; V = Vowel), CVR (R = Sonorant consonant); and CVO (O = Obstruent), based on which the author further proposed that there are only two tones

for CVO syllables: high and low. The author then conducted a tonal contrast study to investigate tonal inventories in syllables with different rhyme durations in Nanchang Chinese and found that some tones are neutralized in syllables with shorter rhyme duration. The discrepancies regarding the syllables structures and the further study focus & conclusion between Liu (2010) and the current study may be that we are looking at two different varieties of NCG. As Sun (2007) briefly mentions, NCG differs in regions, as the NCG spoken in the city of Nanchang is usually called *city dialect* (which is the focus of the current study) whereas the NCG spoken in towns & districts near the city is called *town dialect*. Though Sun (2007) does not go further to explain the specific differences between those two varieties, it is possible that two studies are looking at different varieties with different syllable structures.

2.2. Tone Bearing Unit (TBU)

Tonal languages may differ by the tone bearing unit they choose, the decision of TBU is important in that it tells the scope of the prosodic category we need to focus on in NCG.

There has never been a consensus on the TBU for Chinese languages, as some scholars treat it on the syllable level, while others put it on the moraic level. Chen (1991) discussed specifically various Chinese dialects related to their TBU and has argued that for the majority of Chinese languages (i.e., Beijing, Zhangping, Danyang), TBU is the syllable, though he did mention the exception of New Shanghai showing the transition from a s (syllable)-tone language to a w (word)-tone language, as it tends to spread the initial tone over the entire compound. Supporters of moraic TBU (i.e., Wright 1983), consider tone sandhi (TS) as the result of stress/feet-level sandhi. Usually, every foot consists of two or three syllables, with a strongly stressed syllable grouped with one or two weakly stressed syllables. The strong syllables inherit the property of longer duration & higher amplitude that made them audibly prominent. During the TS process,

the first mora of the weak syllable gets deleted, and the floating tone gets deleted based on language-specific rules, then the weakly stressed syllables are shown to have shortened duration and loss of part or all of the original distinctive tonal contour. When it comes to the analysis of tones in Nanchang Gan (NCG), I prefer to consider the nature of TBU as a syllable. Based on the auditory impression from me as a native speaker, the directionality of the strong stress (which is based on the intensity) is not consistent throughout the language. For example, [t͡ɕɛ ɸən] 'to get married' exhibits a right-strong stress foot, by having the second syllable [ɸən] strong, while some other words like [t͡ɕɛ pa] 'to stammer' are left-stressed. In addition, unlike English, in which the position of stress indicates predictable lexical differences (i.e., [rɛ'kɔd] 'record, V' vs. ['rɛkɔd] 'record, N'), it seems that the stress in NCG cannot be predicted by lexical categories. Therefore, it is hard to generalize stress in NCG as simply right/left-stress foot language, nor could the stress be a reliable predictor of the lexical categories in this language. It is reasonable for me to analyze tones in NCG on syllable level. This decision is crucial for my following research methodology, as I look at tones of monosyllabic words as well as their behaviors when put into disyllabic compounds.

2.3. Directional Prosodic System

The decision of the directional prosodic system in NCG is crucial when it comes to the methods of my future data collection. It would be reasonable to only focus on the TS patterns between the monosyllabic words and the initial syllable of the disyllabic compounds since based on the assumption, we wouldn't expect any tonal changes on the second syllable.

Previous studies have been discussing the directional prosodic system, and how they varied from each other. Particularly, Zhang 2007 and Chen 1991 both talked about this phenomenon in Chinese languages. Tone sandhi directionality can either be right-dominant or left-dominant.

This means whichever tone bearing unit (TBU) being dominant is the one that remains the same during the TS process, while the rest of the TBU undergo the tonal change. It is also well noticed that certain tone sandhi patterns are more common in one directional prosodic system while other TS patterns prefer another one: left-dominant TS shows preference to rightward tone extension, while right-dominant TS prefers leftward neutralization/insertion. Also, as has been observed, there is a geographical preference for the distribution of directionality.

FIGURE 2: Distribution of TS directionality[2]

By summarizing the distributional preference of the major cities in China, we can obtain a general idea of the distribution (with reference to *Figure 2*): right-dominant TS can be mainly found in the Northern area, centered around the capital city Beijing, as well as in the Southeastern cities like Wenzhou; left-dominant TS is concentrated around Zhejiang Province, in cities like Shanghai and Changzhou. This information helps me a lot when deciding which

[2] Based on Language Atlas of China, by Stephen Adolphe Wurm, Rong Li, Theo Baumann and Mei W. Lee, Longman, 1987, ISBN 978-962-359-085-3.

directionality fits my project language - Nanchang Gan (NCG). Though no investigation has been made so far on this aspect of NCG, based on the geographic evidence that Nanchang being far from the Shanghai area and close to Wuyi, as well as the dialect phonetic similarity from a native speaker that NCG being similar to Beijing but different vastly from Shanghai, I made the assumption that NGC tone sandhi should be categorized as right-dominant, which means in a disyllabic compound, the tone on the second syllable remains unchanged, while the initial one undergoes TS. The assumption was later confirmed in the analysis as the data shows that the second syllable keeps its source tone while the first one does not.

Another indispensable piece of information regarding the preferred TS pattern (i.e., either tone neutralization or extension) should be considered in companion with the practical data. By looking into the previously collected data of NGC (a word list of monosyllabic words and their corresponding disyllabic compounds), some general TS patterns can be observed: high tone becomes high-falling tone when followed by a low-rising tone; high tone becomes high-falling tone when followed by a falling-rising tone; high-falling tone becomes a high tone when followed by a low-rising tone Although the previous data is imperfect in many ways and recollection surely in by summarizing the distributional preference of the major cities in China, we can obtain a general idea of the distribution: right-dominant TS can be mainly found in the Northern area, centered around the capital city Beijing, as well as in the Southeastern cities like Wenzhou; left-dominant TS is concentrated around Zhejiang Province, in cities like Shanghai and Changzhou. This information helps me a lot when deciding which directionality does my project language-Nanchang Gan (NCG) fits. Though no investigation has been made so far on this aspect of NCG, based on the geographic evidence that Nanchang being far from the Shanghai area and close to Wuyi, as well as the dialect phonetic similarity from a native speaker

that NCG being similar to Beijing but different vastly from Shanghai, I assume that NGC tone sandhi should be categorized as right-dominant, which means in a disyllabic compound, the tone on the second syllable remain unchanged, while the initial one undergoes TS.

As we can see from those patterns, the TS here exhibits a way of neutralization, as some tones lose their contrastiveness and thus are neutralized in the tone sandhi process. In addition, this is supported by the evidence from a well-documented Chinese language called Wuyi, as a right-dominant city that is geographically closed to Nanchang, it also displays the neutralization pattern by preserving the original tone of the final syllable, while neutralizing the nonfinal one into two level tones.

2.4. Phrase vs. Compound

The discussion of morphological form in NCG is indispensable for this project, as the distinction between phrase and compound may place a significant effect on their tonal behavior. Thus, it is ideal to control the word structure in the data so that it will not distract our attention from analyzing tonal behavior while concerning the phrase versus compound distinction and whether it may cast an influence on the tonal behavior. In this section, I propose that all the words in the disyllabic list should be analyzed as compounds instead of phrases.

Research related to the morphology of Mandarin Chinese has long been discussed while the morphonology of the NCG is extremely rare, it is mainly contributed to the fact that NCG, just like most of the Chinese languages, is an analytic language. That is, a word is not made up of component parts but a single morpheme (Li, et. al, 1981). NCG is written with Chinese characters and NCG speakers use written Chinese, which is used by all Chinese speakers.

As pointed out by Li et al. (1981) in “Mandarin Chinese: A Functional Reference Grammar”, there have been numerous studies of compounds in Mandarin Chinese, and it is difficult to have

one decisive definition of compound in Chinese. Nevertheless, studies such as Chao (1968) reached a consensus that in Chinese languages, the relatedness between the semantic meaning of the compound and those of its component morphemes can vary from close to nonexistent. This complex phenomenon arises from the fact that many morphemes may come from the classical Chinese and are not used as a free morpheme with independent meaning in modern Chinese anymore. For example, in my data, [ɸa ɕiu] 发笑 'to laugh' consists of a bound morpheme [ɸa] and a free morpheme [xiu]. The bound morpheme was originally free in classic Chinese meaning 'to arise from', but now must occur as a bound morpheme. Li et al. (1981) proposed three general types of Chinese compound defined by their distinctive and various degrees of relatedness between the semantic meaning of the whole word and the meaning of its component morphemes, which is crucial for identifying compounds, and here I use to testify the word structure of my data in this study. Li et al. (1981) propose the following three types of Chinese compounds:

I. There may be no apparent semantic connection between the meaning of the compound and the meaning of its constituents in the modern language. Such compounds exhibit the highest degree of idiomaticity. Very few compounds in Mandarin, however, are of this type.
II. There may be metaphorical, figurative, or inferential connection between the meaning of the compound and the meanings of its component parts.
III. The meaning of the compound may be directly related or identical to the meaning of its components.

In my data, there is no type I compound, which means there should be at least some degrees of relatedness between the word and the individual morphemes. An example of type II compound would be [k^ha $tɕ^hi$] 客气 'friendly (especially when you are greeting the guests)', in which the first morpheme [k^ha] means 'guest' and the second morpheme [$tɕ^hi$] means 'air/vibe'. It is a type II compound as it can be inferred that the vibe between you and your guests should be friendly.

Most of the words as my data in the project are the type III compounds, which means there is a direct corresponding meaning between the word and the morphemes within. An example of that from my wordlist would be [ɸa sui] 划水 'to paddle', in which the first morpheme [ɸa] means 'to paddle' and the second morpheme [sui] means 'water'. It is a type III compound as the meaning of the word 'to paddle' is identical to the meanings of its parts.

Additionally, Haspelmath and Sims (2010) point out semantic, phonological, morphological and syntactic criteria for further distinguishing phrases and compounds (Table 3) as the previous definition of the Type III compound is exactly what we would expect for phrases as well, thus deeper criteria is needed for further clarification. Here the criteria relating specifically to this study include: in compounds, the dependent noun may not be replaced by an anaphoric pronoun (NRA), as they are inseparable (IS), and the ellipsis is impossible (EI). The applied criteria were presented and explained in Chapter 4.

TABLE 3: Phrases versus compounds

	Phrases	**Compounds**
semantic	dependent noun may be referential head may be replaced by an anaphoric pronoun	dependent noun virtually always generic head may not be replaced by an anaphoric pronoun
phonological	less cohesion	greater cohesion e.g. compound as domain of stress assignment, vowel harmony
morphological	no cohesion	greater cohesion e.g. compound as domain of affixation
syntactic	separable dependent noun expandable coordination ellipsis possible	inseparable dependent noun not expandable coordination ellipsis impossible

CHAPTER 3: TONES OF MONOSYLLABIC WORDS

3.1. Methodology

I modeled my methodology primarily on Fischer (2013). Over the years, some scholars have contributed to the methodologies of measuring tones. Among them, the methodology used by Fischer (2013) emerged to be the most appealing and feasible candidate for my project for measuring tones. Her research focuses on the phonetic characteristics and provides a phonemic analysis of Sgaw Karen. When measuring tones, she sliced each vowel into 20 equal slices and extract pitch contours of the vowel, the average, and its standard deviation for each tone was then calculated as well. Based on her studies, it is found that the outlier and higher average deviations occurred within the first or last one to two slices (i.e., the first and last 5-10% of the vowel). This observed larger variation was likely due to coarticulatory effects with the consonant in the first and last 5-10% of the vowel. Thus, the first and last 10% vowel duration was not taking into account for further tonal analysis. The methodology looks appealing to me in that it can nicely cover the details of the pitch contour, as well as excluding potential interference factors.

3.1.1. Stimulus

To look at tones in NCG and its potential TS pattern, it is necessary to look at tones in monosyllabic words and comparing that with their behaviors when they are put into disyllabic compounds.

A wordlist of 15 monosyllabic words was collected, which includes three sets of monosyllabic words (Table 4): [ka/kʰa], [ɲa/ɲɛ/ŋa] and [ɸa], with each of them having five

distinctive tones (thus are distinctive lexically), and vowels are controlled so that they are restricted to [a] or [ɛ]. In the table below, mid falling tone and mid tone are the new categories, proposed in the current study, which are different from Yuan (1989)'s & Liu (2010)'s proposals.

TABLE 4: Monosyllabic wordlist

	[ka/kʰa]	[ɲa/ɲɛ/ŋa]	[ɸa]
Mid falling	[ka] 加 'to add up'	[ɲa] 压 'pressure'	花 'flower'
High rising	[kʰa] 客 'guest'	[ɲɛ] 热 'hot'	罚 'penalty'
Falling rising	[ka] 假 'fake'	[ŋa] 哑 'mute'	画 'to paint'
Low rising	[ka] 嫁 'to marry'	[ŋa] 牙 'tooth'	划 'to paddle'
Mid	[ka] 架 'frame'	[ɲɛ] 鱼 'fish'	发 'to cause'

3.1.2. Participant

All the recordings (both the monosyllabic words and the dissyllabic ones) were completed by me as a female native speaker of NCG, who was born and grew up in the city and is now 25. Mandarin is the official language of the city used in every official situation, thus participants picked up NCG from informal situations (i.e., grocery stores, small shopping malls), mostly at home and with friends. Besides NCG and Mandarin, I have been exposed to English since 4 in

preschool and have been studying abroad for 5 years in Canada and the United States. I'm currently a MA student studying linguistics at the University of North Carolina at Chapel Hill. Since college, there is less opportunity for me to speak NCG, I only have a chance to practice it when I go back home, which happens once a year, or I speak it with my family when I video chat with them.

3.1.3. Data Collection

The monosyllabic list consists of three monosyllabic words each of which has five tones, and each was recorded with three repetitions in a row, this gave me 3*5*3 = 45 utterances in total. Due to the Covid-19, recordings were done at the native speaker's house, the whole procedure was about one hour long. the words were presented in a list on paper. There was a 30-second break between each word. Items were recorded in isolation, with each recording stored as separate files on a MacBook. Recordings were made in Praat version 6.1.38 (Boersma and Weenink 2021) on a Macbook MacOsX version 10.15.6 using a hands-free, headset microphone. Elicitation for tones began with monosyllables and the native speaker came up with different tones that can be borne with them to lexical words in NCG.

3.1.4. Data Analysis

Once collected, Praat (Boersma and Weenink 2021) was used for measuring tones. Syllable boundaries were demarcated in a Textgrid, for each token, pitch contour was extracted by choosing *Extract Visible Pitch Contour* from the pitch menu, the extracted pitch contour was saved as a separate pitch object to the *List of Objects*. To do this, pitch was extracted manually using the pitch setting specified in *Table 5.* Then a Praat script was used to slice the pitch extract into 20 equal slices and extract the mean fundamental frequency (F0), maximal F0, minimal F0

at each of that 20 measurement-point, but only 18 measurement-points were taken into the analysis (the first and the last point were excluded due to coarticulation effect concern).

TABLE 5: Pitch settings in Praat (Boersma & Weenink 2021) for tonal analysis of monosyllabic words

Setting	Value
Start of pitch range	75
End of pitch range	500
Analysis method	Autocorrection
Drawing method	Automatic

3.1.5. Statistical Analysis

The statistical analysis was based on Tang et al (2019), in the paper, the authors investigated the productions of tone sandhi by Mandarin-speaking children and compared that to the adult productions. Acoustic analysis as well as statistical analysis were both implemented when exploring tone productions. For the statistical analysis, the data were analyzed in R (R Core Team, 2020). A second-order orthogonal polynomial equation was fitted for each production by using poly function of R as the most complex pitch contour of tones had only convex or a concave contour shape. Mirman (2014) has proposed three parameters for tone measurements:

> The three parameters, respectively, capture the pitch onset (as reflected in the intercept: the higher the intercept, the higher the pitch onset value), direction (slope as reflected in the linear trend: a positive value indicates a rising pitch and a negative value a falling pitch, with a large value representing steepness), and curvature (as reflected in the quadratic trend: a positive quadratic trend indicates a concave f0 contour, a negative quadratic trend indicates a convex contour; and a large quadratic trend indicates a more curved f0 contour and vice versa). These parameters were used to evaluate any group differences in the overall f0 contour.

For the statistical analysis of the monosyllabic list, R (R Core Team, 2020) was used to do the analysis: based on the raw values, I used the poly() function in R to generate three parameters, and like Tang et al (2019), the study only focuses on intercept, pitch slope and curvatures as parameters to examine any group differences as NCG is characterized by distinctive pitch contours. With the help of the expert in the Odum Institute at UNC-CH, intercept, slope, and curvature means were each modeled as a function of tone type using a mixed linear regression model with fixed mean effects for each tone type and a random mean effect for each utterance. Within the context of these three models, all tone types means were compared, pairwise.

This statistical methodology fits well with my project as I am also exploring tone sandhi, though I did not compare between different age groups but different morphological structures (monosyllabic vs. disyllabic) instead. Besides, the language I'm looking into is NCG, which, just like Mandarin, has concave or convex as its most complex shape, thus the second-order orthogonal polynomial equation fitted well in my data.

3.2. Result

Figure 3-7 show the behaviors of each utterance for each of the five monosyllabic tones, with each set of words color-coded: [ka/kʰa]-green, [ɲa/ɲɛ/ŋa]-red and [ɸa]-blue. It shows that the tones of the data are generally in good consistency regarding their individual utterances, though a few inconsistencies can be observed here: the three sets of words display three different levels of low rising tone, with [ka/kʰa] being the highest, followed by [ɲa/ɲɛ/ŋa], and then [ɸa]; moreover, utterances behave inconsistently for the high rising tone, as the [kʰa] words are generally higher than the other two sets. This observation can be supported by what Fulop & Deng (2016) brought up in "Interaction between aspiration and tonal pitch in Weihai Chinese",

that voiceless velar stop onsets appear to raise the tonal pitch when aspirated. There seems to be no conclusive explanation for the effect of place of articulation so far, but they did argue that the pitch effects are related to the increased stiffness of the vocal cords during voiceless obstruent production, compared to voiced obstruent.

Overall, visual inspections support the previous claim that there are five distinctive tones in NCG: mid tone (Figure 3), falling rising tone (Figure 4), low rising tone (Figure 5), high rising tone (Figure 6) and mid falling tone (Figure 7).

FIGURE 3: Individual utterances for mid tone

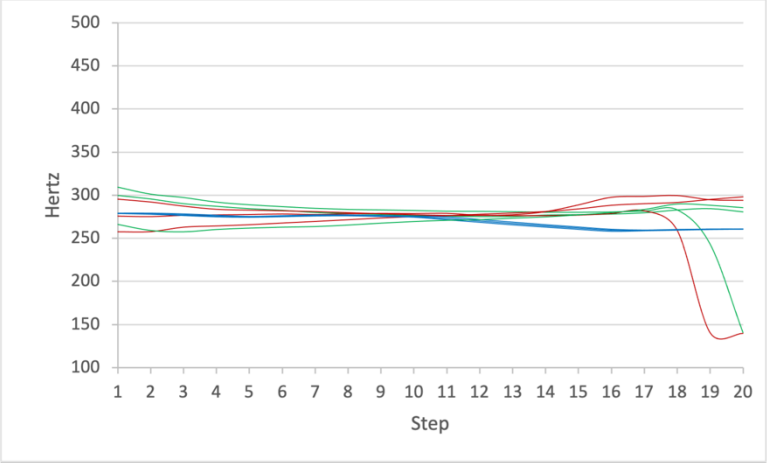


FIGURE 4: Individual utterances for falling rising tone

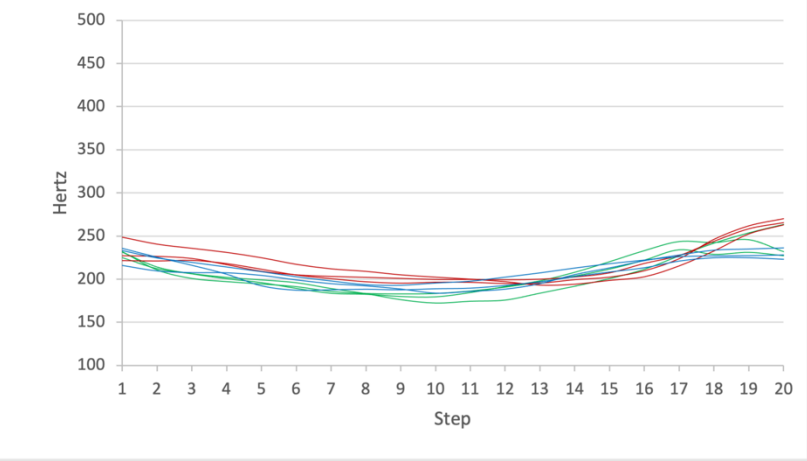


FIGURE 5: Individual utterances for low rising tone

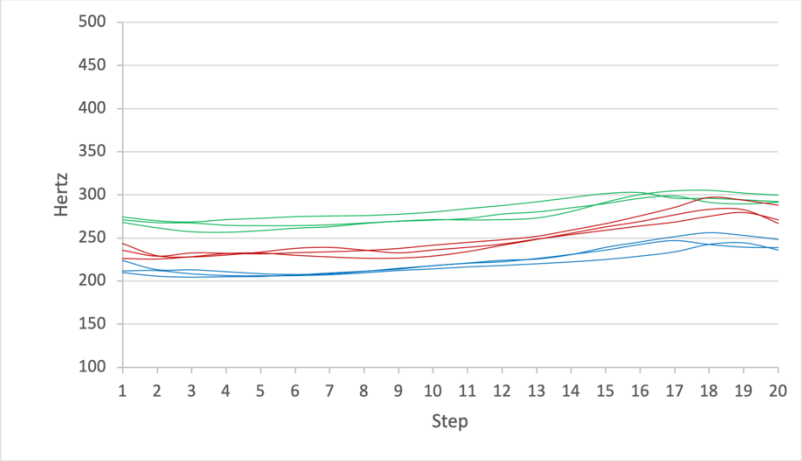


FIGURE 6: Individual utterances for high rising tone

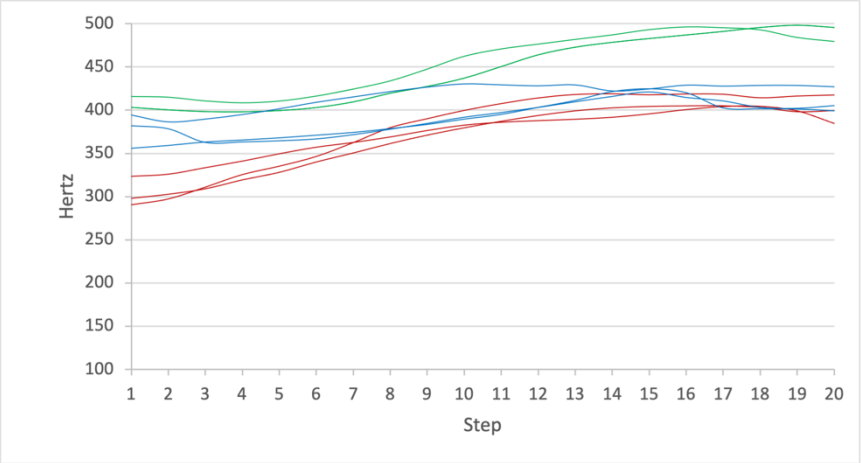


FIGURE 7: Individual utterances for mid falling tone

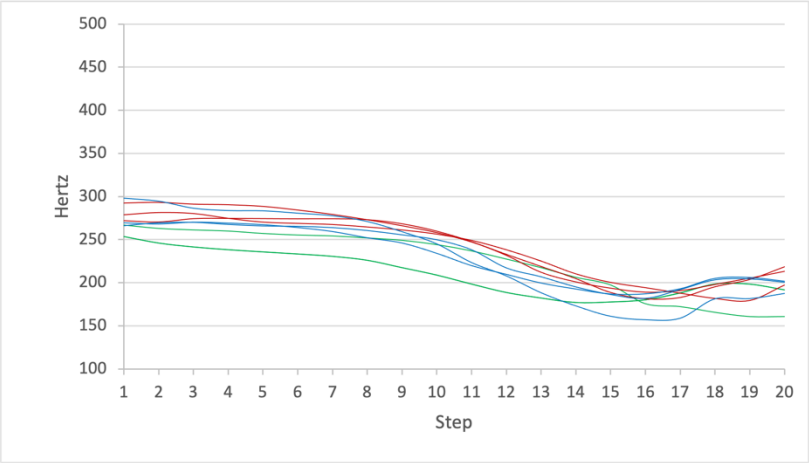


Table 6 is a summary table showing the results of the pairwise comparison of parameters for the monosyllabic contrast (please find the full table in Appendix 1). The statistical results below (Table 6) also support the five distinctive tones in NCG, results of pairwise comparison on the three pitch parameters (intercept, slope and curvature) of NCG lexical tones show that regarding tonal contrast, there is at least one parameter that is significantly different, which makes the five tones significantly different with each other via pairwise comparison. Moreover, some tones are more similar with each other than others, for example, mid tone, high rising, and mid falling tone all share similar curvature as the statistics show only significantly different in slope & intercept; while falling rising tone and low rising tone both share similar pitch direction (reflected as slope), as they are only significantly different in terms of curvature and the initial F_0 values for the tones.

To sum up, the current findings collapse with the previous finding on the view that there are five monosyllabic lexical tones in NCG, however, as I will explain in the section below, there exists discrepancy which needs to be pointed out and possibly explore here.

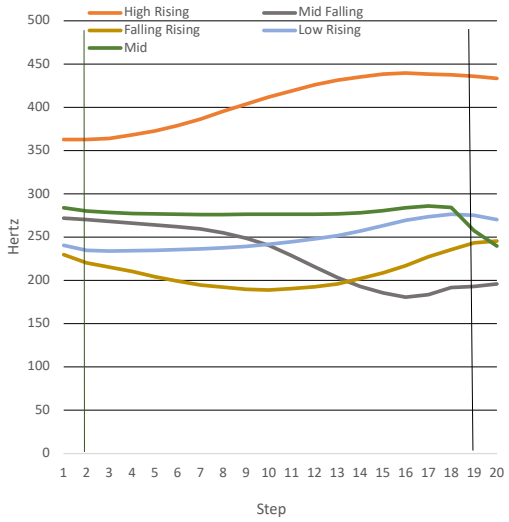
TABLE 6: Summary of the results of pairwise comparison of parameters for the monosyllabic contrasts

	Intercept	Slope	Curvature
High rising-mid falling	***	***	
High rising-falling rising	***	***	***
High rising-low rising	***	**	***
High rising-mid	***	***	
Mid falling-falling rising	**	***	***
Mid falling-low rising	*	***	**
Mid falling-mid	***	***	
Falling rising-low rising	***		***
Falling rising-mid	***	**	***
Low rising-mid		***	*

3.3. Discussion

So far, I have proved that, first of all, there are five monosyllabic lexical tones in NCG. Moreover, after plotting the five tones together (see Figure 8), it seems necessary to relabel some of the pre-proposed tones.

FIGURE 8: NCG monosyllabic tone contours (relabeled)



Based on the plotted figure and their relevant pitch values, five categories of initial F0 values here (which is reflected in the intercept) can be observed. I would further propose that, instead of having high tone and high falling tone as proposed by Yuan (1989) and high tone & low falling tone as proposed by Liu (2010), we should have mid tone and mid falling tone instead. Therefore, according to this revised categorization, there are five monosyllabic tones in NCG: mid tone, falling rising tone, low rising tone, high rising tone and mid falling tone.

Overall, the current results partially support the previous proposals on NCG monosyllabic tones, particularly regarding the number of tones. Here we both agree that there should be five monosyllabic lexical tones in NCG. However, we disagree on some of the categories of the tones. Through careful visual inspections and statistical analysis, I conclude that the five tones

should be categorized as follows: mid tone, falling rising tone, low rising tone, high rising tone and mid falling tone.

CHAPTER 4: TONES OF DISYLLABIC WORDS

4.1. Methodology

The methodology for the disyllabic words is the same for the monosyllabic one, both of them are based on the methodology used by Fischer (2013). Each vowel was sliced into 20 equal slices and the pitch contours were extracted. The three parameters pitch: intercept, slope, and curvature, were later generated using R. To avoid the coarticulatory effect, the first and the last 10% of the vowel were excluded in the further analysis.

4.1.1. Stimuli

For the current study, a disyllabic wordlist was constructed by putting each of the 15 monosyllabic words from the monosyllabic list into 5 disyllabic compounds as the initial syllable (Table 8-10), while each of the second words takes a distinct tone. Here I summarized my disyllabic wordlist and organized it by the compound types as discussed in Chapter 2, incorporating the criteria so that it would straightforwardly clarify the word structures of all the disyllabic words as my data in this study. Here again are the criteria: in compounds, the dependent noun may not be replaced by an anaphoric pronoun (NRA), as they are inseparable (IS), and the ellipsis is impossible (EI).

TABLE 7: Disyllabic words summarized by compound categories

Compound type	Disyllabic word	Meaning of the word	Meaning of the components	Criteria
Type II	[ka sɛ] 假设	'to hypothesize'	'fake-to set up'	
	[kʰa tɕʰi] 客气	'friendly'	'guest-air'	
	[ŋa ɸɔ] 哑火	'dumb fire'	'to mute-fire'	
	[ɲa ka] 压价	'to bargain'	'pressure-price'	
	[ɲa swɛi] 压碎	'to smash'	'pressure-pieces'	
	[ɸa kau] 发糕	'steamed sponge cake'	'fermentative-cake'	
	[ɸa sə] 花色	'design color'	'flower-color'	
Type III	[ka nin] 架人	'to erect someone'	'to put up-people'	NRA
	[ka tɕiŋ] 架景	'aircraft scene'	'aircraft-scene'	IS
	[ka kʰoŋ] 架空	'to build on stilts'	'to build-empty'	NRA
	[kʰa ɕiaɔ] 假笑	'fake smile'	'fake-smile'	IS
	[kʰa si] 假死	'fake death'	'fake-death'	IS
	[kʰa lu] 假如	'if'	'if-if'	EI

	[ka san] 假山	‘rockery’	‘fake-mountain’	IS
	[ka nin] 嫁人	‘to marry’	‘to marry-people’	NRA
	[ka tɕʰy] 嫁娶	‘marriage’	‘to marry-to marry’	EI
	[ka tsɔŋ] 嫁妆	‘dowry’	‘marriage-bridal gift’	IS
	[kʰa nin] 客人	‘guest’	‘guest-people’	IS
	[kʰa tsuən] 客船	‘guest boat’	‘guest-boat’	IS
	[kʰa tsʰa] 客车	‘bus’	‘guest-vehicle’	IS
	[ka iyu] 加油	‘to refuel’	‘to add (up)-oil’	NRA
	[ka ɸa] 加法	‘addition’	‘to add up-principle’	IS
	[ka tsɔŋ] 加床	‘to add a bed’	‘to add-bed’	NRA
	[ka su] 加速	‘to speed up’	‘to add up-speed’	NRA
	[ka pan] 加班	‘to work overtime’	‘to add-(working) shift’	NRA
	[ɲɛ iyu] 鱼油	‘fish oil’	‘fish-oil’	IS
	[ɲɛ tsʰɨ] 鱼刺	‘fishbone’	‘fish-bone’	IS
	[ɲɛ tou] 鱼头	‘fish head’	‘fish head’	IS
	[ɲɛ gao] 鱼糕	‘fish cake’	‘fish cake’	IS
	[ŋa tɕu] 哑剧	‘mime’	‘to mute-opera’	IS

	[ŋa pa] 哑巴	‘a dumb person’	‘mute- (no independent meaning)’	IS
	[ŋa in] 牙龈	‘gums’	‘tooth-gum’	IS
	[ŋa tsʰɨ] 牙齿	‘tooth’	‘tooth-tooth’	IS
	[ŋa suɔ] 牙刷	‘toothbrush’	‘tooth-brush’	IS
	[ŋa kaɔ] 牙膏	‘toothpaste’	‘tooth-paste’	IS
	[ɲɛ nin] 热人	‘to make people feel hot’	‘to warm-people’	NRA
	[ɲɛ tʰiɛn] 热天	‘hot day’	‘hot-day’	IS
	[ɲa po] 压迫	‘to oppresses’	‘pressure-to force’	NRA
	[ɸa ɕiu] 发笑	‘to laugh’	‘to cause-laugh’	NRA
	[ɸa piŋ] 发病	‘to get sick’	‘to cause-illness’	NRA
	[ɸa tsʰai] 发财	‘to become rich’	‘to cause-possession’	NRA
	[ɸa ɲɛ] 发热	‘to have a fever’	‘to cause/stimulate-fever’	NRA
	[ɸa nin] 画人	‘to paint portrait’	‘to paint-people’	NRA
	[ɸa ɸa] 画画	‘to paint’	‘to paint-painting’	NRA
	[ɸa ɕiɔŋ] 画像	‘portrait’	‘painting-portrait’	IS
	[ɸa ka] 划价	‘to have a prescription priced’	‘to assign (a value)-price’	NRA

	[ɸa sui] 划水	‘to paddle’	‘to paddle-water’	NRA
	[ɸa tsʰuan] 划船	‘to paddle a boat’	‘to paddle-boat’	NRA
	[ɸa ɸɛn] 划分	‘partition	‘to split-divide’	IS
	[ɸa tsan] 罚站	‘to stand in the corner (as a punishment)’	‘penalty-to sand up’	NRA
	[ɸa kʰuan] 罚款	‘penalty’	‘penalty-fee’	IS
	[ɸa tɕʰiy] 罚球	‘penalty kick’	‘penalty-ball’	IS
	[ɸa ɸɛn] 罚分	‘penalty point’	‘penalty-point’	IS
	[ɸa iuan] 花园	‘garden’	‘flower-garden’	IS
	[ɸa tɔ] 花朵	‘flower’	‘flower-(no independent meaning’	IS
	[ɸa tɕʰiy] 花球	‘flower ball’	‘flower-ball’	IS
	[ɸa tsa] 花车	‘flower car’	‘flower-car’	IS

The above table proves that all the disyllabic words in this study should be categorized as compounds instead of phrases based on the above criteria. This confirmation is crucial as it helps

to eliminate the concerns that different word structures in the data may place a significant effect on their tonal behavior of this study.

This gave me 56 disyllabic words in total, as some of the monosyllabic words carrying certain lexical tones cannot be phrased into a disyllabic word (i.e., [ka] (嫁; 'to marry') cannot be combined with a high-rising monosyllabic word. The phonetic transcription of each syllable in the disyllabic words was also shown in the row below the whole transcription & gloss of the disyllabic words. The upper cell stands for the initial syllable (i.e., [ka] 'to erect' in [ka nin] 架人 'to erect someone'), and the lower cell stand for the second syllable (i.e., [nin] 'someone' in [ka nin] 架人 'to erect someone'). The list consists of a mixed number of nouns and verbs, as it is difficult to come up with words of specific tones while also controlling the lexical category. Because the wordlist is initially constructed based on the auditory judgment of the native speaker, the tones of some words may turn out not have the tones I expected before, hence one additional backup disyllabic word was provided if possible. However, noted that every decision of the wordlists is made by one single native speaker, to which the narrow scope of the research is certain to be attributed, expended objects is key to further implementation.

Table 8: Disyllabic list of [ka/k^{h}a]

	1st σ	**2nd σ**	**1st σ**	**2nd σ**	**1st σ**	**2nd σ**	**1st σ**	**2nd σ**	**1st σ**	**2nd σ**
2nd σ / 1st σ	**Mid level**		**Falling rising**		**Low rising**		**High rising**		**Mid falling**	
Mid level	[ka nin]				[ka tɕiŋ]				[ka k^{h}oŋ] 架空 'to build on stilts'	

	架人 ‘to erect someone’		架景 ‘aircraft scene’		
	[ka] ‘to put up’		[ka] ‘aircraft’		[ka] ‘to build up’
	[nin] ‘people’		[ga] ‘scene’		[kʰoŋ] “empty’
Falling rising	[kʰa ɕiaɔ] 假笑 ‘fake smile’	[kʰa si] 假死 ‘fake death’	[kʰa lu] 假如 ‘if’	[ka sɛ] 假设‘to hypothesize’	[ka san] 假山 ‘rockery’
	[kʰa] ‘fake’	[kʰa] ‘fake’	[kʰa] ‘if’	[ka] ‘fake’	[ka] ‘fake’
	[ɕiaɔ] ‘smile’	[si] ‘death’	[lu] ‘if’	[sɛ] ‘to set up’	[san] ‘mountain’
Low rising	[ka nin] 嫁人 ‘to marry’	[ka tɕʰy] 嫁娶‘marriage’			[ka tsɔŋ] 嫁妆 ‘dowry’
	[ka] ‘to marry’	[ka] ‘to marry’			[ka] ‘to marry’
	[nin] ‘people’	[tɕʰy] ‘to marry’			[tsɔŋ] ‘bridal gift’
High rising	[kʰa nin] 客人 ‘guest’	[kʰa tɕʰi]	[kʰa tsuən]		[kʰa tsʰa] 客车 ‘bus’

		客气 ‘friendly’	客船 ‘guest boat’		
	[kʰa] ‘guest’	[kʰa] ‘guest’	[kʰa] ‘guest’		[kʰa] ‘guest’
	[nin] ‘people’	[tɕʰi] ‘air’	[tsuən] ‘boat’		[tsʰa] ‘vehicle’
Mid falling	[ka iyu] 加油 ‘to refuel’	[ka ɸa] 加法 ‘addition’	[ka tsɔŋ] 加床 ‘to add a bed’	[ka su] 加速 ‘to speed up’	[ka pan] 加班 ‘to work overtime’
	[ka] ‘to add (up)’	[ka] ‘to add up’	[ka] ‘to add’	[ka] ‘to add up’	[ka] ‘to add up’
	[iyu] ‘oil’	[ɸa] ‘principle’	[tsɔŋ] ‘bed’	[su] ‘speed’	[pan] ‘(working) shift’

Table 9: Disyllabic list of [ɲa/ɲɛ/ŋa]

	1st σ	**2ndσ**	**1st σ**	**2ndσ**	**1st σ**	**2ndσ**	**1st σ**	**2ndσ**	**1st σ**	**2ndσ**
2ndσ / 1st σ	**Mid level**		**Falling rising**		**Low rising**		**High rising**		**Mid falling**	
Mid level	[ɲɛ iyu] 鱼油 ‘fish oil’		[ɲɛ tsʰɨ] 鱼刺 ‘fishbone’		[ɲɛ tou] 鱼头 ‘fish head’				[ɲɛ gao] 鱼糕‘fish cake’	

	[ɲɛ] ‘fish’	[ɲɛ] ‘fish’	[ɲɛ] ‘fish’		
	[iyu]‘oil’	[tsʰɨ] ‘bone’	[tou] ‘head’		
Falling rising	[ŋa tɕu] 哑剧‘mime’	[ŋa ɸɔ] 哑火 ‘dumb fire’			[ŋa pa] 哑巴 ‘a dumb person’
	[ŋa] ‘to mute’	[ŋa] ‘to mute’			[ŋa] ‘mute’
	[tɕu] ‘opera’	[ɸɔ] ‘fire’			[pa] (no independent meaning)
Low rising	[ŋa in] 牙龈 ‘gums’	[ŋa tsʰɨ] 牙齿 ‘tooth’		[ŋa suɔ] 牙刷‘tooth brush’	[ŋa kaɔ] 牙膏 ‘toothpaste’
	[ŋa] ‘tooth’	[ŋa] ‘tooth’		[ŋa] ‘tooth’	[ŋa] ‘tooth’
	[in] ‘gum’	[tsʰɨ] ‘tooth’		[suɔ] ‘brush’	[kaɔ] ‘paste’
High rising	[ɲɛ nin] 热人‘to make people feel hot’		[ɲɛ tʰien] 热天‘hot day’		
	[ɲɛ] ‘to warm’		[ɲɛ] ‘hot’		

	[nin] ‘people’		[tʰiɛn] ‘day		
Mid falling	[ɲa ka] 压价 ‘to bargain’	[ɲa po] 压迫 ‘to oppress’	[ɲa suɛi] 压碎 ‘to smash’		
	[ɲa] ‘pressure’	[ɲa] ‘pressure’	[ɲa] ‘pressure’		
	[ka] ‘price’	[i] ‘to force’	[suɛi] ‘piece’		

Table 10: Disyllabic list of [ɸa]

	1st σ **2ndσ**	**1st σ** **2ndσ**	**1st σ** **2ndσ**	**1st σ** **2ndσ**	**1st σ** **2ndσ**
2ndσ / **1st σ**	**Mid level**	**Falling rising**	**Low rising**	**High rising**	**Mid falling**
Mid level	[ɸa ɕiu] 发笑 ‘to laugh’	[ɸa piŋ] 发病 ‘to get sick’	[ɸa tsʰai] 发财 ‘to become rich’	[ɸa ɲɛ] 发热 ‘to have a fever’	[ɸa kau] 发糕 ‘steamed sponge cake’
	[ɸa] ‘to cause’	[ɸa] ‘to cause’	[ɸa] ‘to cause’	[ɸa] ‘to stimulate’	[ɸa] ‘fermentative’
	[ɕiu] ‘to laugh	[pin] ‘illness’	[tsʰai] ‘possession’	[ɲɛ] ‘fever’	[kau] ‘cake’

Falling rising	[ɸa nin] 画人 ‘to paint portrait’	[ɸa ɸa] 画画 ‘to paint’	[ɸa ɕiɔŋ] 画像 ‘portrait’		
	[ɸa] ‘to paint’	[ɸa] ‘to paint’	[ɸa] ‘painting’		
	[nin] ‘people’	[ɸa] ‘a picture’	[ɕiɔŋ] ‘portrait’		
Low rising	[ɸa ka] 划价 ‘to have a prescription priced’	[ɸa sui] 划水 ‘to paddle’	[ɸa tsʰuan] 划船 ‘to paddle a boat’		[ɸa ɸɛn] 划分 ‘to divide’
	[ɸa] ‘to assign (a value)’ [ka] ‘price’	[ɸa] ‘to paddle’ [sui] ‘water’	[ɸa] ‘to paddle’ [tsʰuan] ‘a boat’		[ɸa] ‘to split’ [ɸɛn] ‘to divide’
High rising	[ɸa tsan] 罚站 ‘to stand in the corner (as a punishment)’	[ɸa kʰuan] 罚款 ‘penalty’	[ɸa tɕʰiy] 罚球 ‘penalty kick’		[ɸa ɸɛn] 罚分 ‘penalty point’
	[ɸa] ‘penalty’	[ɸa] ‘penalty’	[ɸa] ‘penalty’		[ɸa] ‘penalty’

	[tsan] ‘to stand up’	[kʰuan] ‘fee’	[tɕʰiy] ‘ball’		[ɸɛn] ‘point’
Mid falling	[ɸa iuan] 花园 ‘garden’	[ɸa tɔ] 花朵 ‘flower’	[ɸa tɕʰiy] 花球‘flower ball’	[ɸa sə] 花色‘design color’	[ɸa tsa] 花车 ‘flower car’
	[ɸa] ‘flower’	[ɸa] ‘flower’	[ɸa] ‘flower’	[ɸa] ‘design’	[ɸa] ‘flower’
	[iuan] ‘garden’	[tɔ] ‘PATICLE’	[tɕʰiy] ‘ball’	[sə] ‘color’	[tsa] ‘car’

Here is the summary table showing how many utterances there are for each tone combination in the disyllabic words:

Table 11: Summarized disyllabic wordlist

2nd σ / 1st σ	Mid	Falling rising	Low rising	High rising	Mid falling
Mid	ka; ɲɛ; ɸa	ɲɛ; ɸa	ka; ɲɛ; ɸa	ɸa	ka; ɸa
Falling rising	kʰa; ŋa; ɸa	kʰa; ŋa; ɸa	kʰa; ɸa	ka	ka; ŋa
Low rising	ka; ŋa; ɸa	ka; ŋa; ɸa	ɸa	ŋa	ka; ŋa; ɸa
High rising	kʰa; ɲɛ; ɸa	kʰa; ɸa	kʰa; ɲɛ; ɸa		kʰa; ɸa
Mid falling	ka; ŋa; ɸa	ka; ɲa; ɸa	ka; ɲa; ɸa	ka; ɸa	ka; ɸa

Here is what each disyllabic word looks at separately, the blank means there is at least one tone combination found, and ∅ means null. There are 20 words for [ka/kʰa], 15 for [ɲa/ɲɛ/ŋa] and 21 for [ɸa]. There are 20+15+21=56*3=168 tokens in total.

Table 12: Summary for [ka/kʰa]

2nd σ / 1st σ	Mid	Falling rising	Low rising	High rising	Mid falling
Mid		∅		∅	
Falling rising					
Low rising			∅	∅	
High rising				∅	
Mid ralling					

Table 13: Summary for [ɲa/ɲɛ/ŋa]

2nd σ / 1st σ	Mid	Falling rising	Low rising	High rising	Mid falling
Mid				∅	∅
Falling rising			∅	∅	
Low rising			∅		
High rising		∅		∅	∅
Mid falling				∅	∅

Table 14: Summary for [ϕa]

2nd σ / 1st σ	Mid	Falling rising	Low rising	High rising	Mid falling
Mid					
Falling rising				∅	∅
Low rising				∅	
High rising				∅	
Mid falling					

4.1.2. Statistical Analysis

Like the monosyllabic analysis, the statistical analysis of the disyllabic words was also based on Tang et al (2019). For the statistical analysis, the data were analyzed in R (R Core Team, 2020). A second-order orthogonal polynomial equation was fitted for each production by using poly function of R. The three parameters (intercept, slope and curvature) from Mirman (2014) were also included in the analysis. Specifically, R (R Core Team, 2020) was used in the analysis: here I used the poly() function in R to generate three parameters, and with the help of the expert in the Odum Institute at UNC-CH, intercept, slope and curvature means were each modeled as a function of tone type combinations using a mixed linear regression model with fixed mean effects for each tone type and a random mean effect for each utterance. Within the context of these three models, all tone type combination means were compared, pairwise. Here specifically, SAS proc mixed version 9.4 was also used to compare the means of each monosyllabic utterances of one tone to those when they were put into different disyllabic contexts, which means all five of the monosyllabic tones were compared to all 24 of the first

syllable of the disyllabic compounds (high rising followed by high rising is missing from the data).

4.2. Result

There are in total eight tones for disyllabic words in NCG. two tones are the same tone from the monosyllabic words: mid tone and low rising tone, and there are six new tones emerged from the data: high tone, low tone, low falling tone, (new) mid falling tone, mid rising tone and a relatively complicated tone 8 (more details later). Readers should notice that there is a new mid falling tone in the disyllabic context, and the new mid falling tone is distinct from the monosyllabic mid falling tone in that it is less steep from the monosyllabic mid falling one which is reflected in their significantly different slope parameter.

Figures 9-14 show the behaviors of each individual utterances for the new tones. Again, each set of words was color-coded: [ka/k^{h}a]-green, [ɲa/ɲɛ/ŋa]-red and [ɸa]-blue. It is noted that some tones ((new) mid falling, mid rising, etc.) display more variability while high tone, low tone and low falling tone behave more consistently. Regarding the (new) mid falling tone, [ɸa] & [ka/k^{h}a] both consistently show mid falling pitch contour while [ɲa/ɲɛ/ŋa] displays a flatter shape, For the mid rising tone, [ka/k^{h}a] displays a clearer mid rising pitch contour while the other two ([ɲa/ɲɛ/ŋa] & [ɸa]) show more level-tone-like, flatter pitch contour with pitch ranges from 250-300 Hz, which resembles a mid tone. It is difficult to define “tone 8” due to the variable behaviors of each utterance, therefore it is wiser to describe each utterance in detail: [ɲa/ɲɛ/ŋa] generally takes the shape of a high tone which ranges from 350-400 Hz, except for one utterance displays a lower pitch ranging from 275-325 Hz. [ka/k^{h}a] is also not behaving consistently, with two of the three utterances showing the mostly collapsing with the lower pitch of [ɲa/ɲɛ/ŋa] and the other one rising slightly from 350 Hz to 400Hz.

FIGURE 9: Individual utterances for high tone

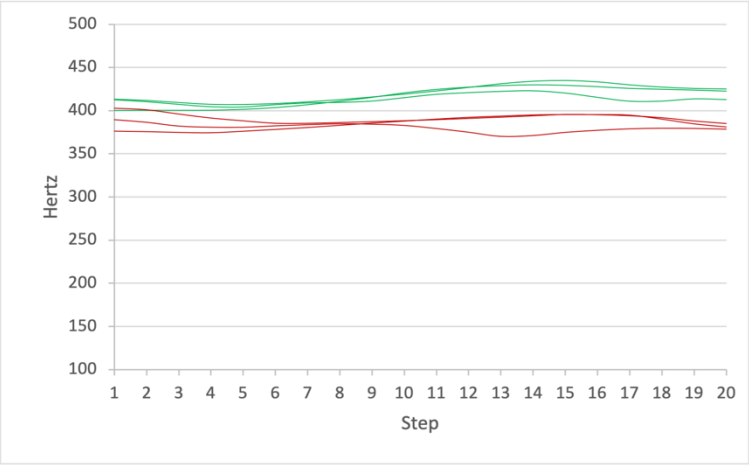


FIGURE 10: Individual utterances for (new) mid falling

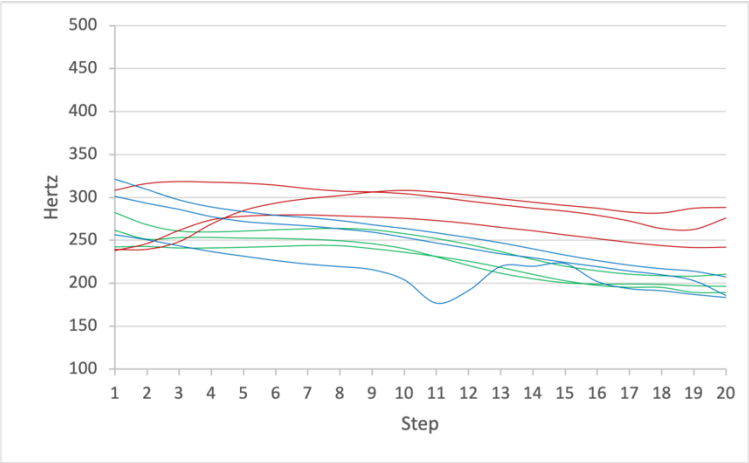


FIGURE 11: Individual utterances for mid rising

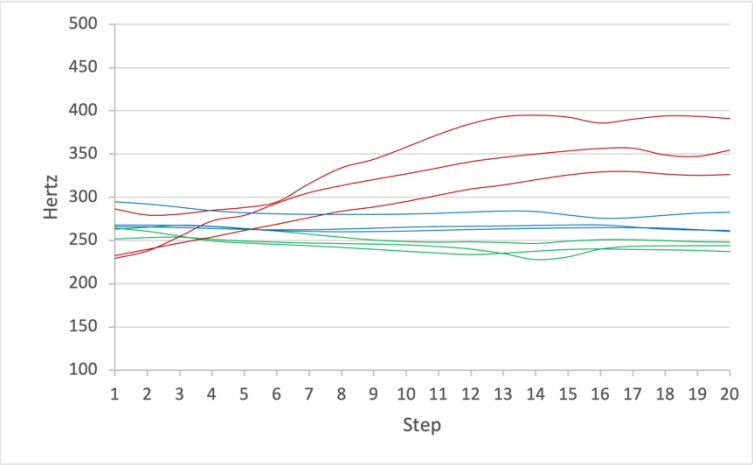


FIGURE 12: Individual utterances for low tone

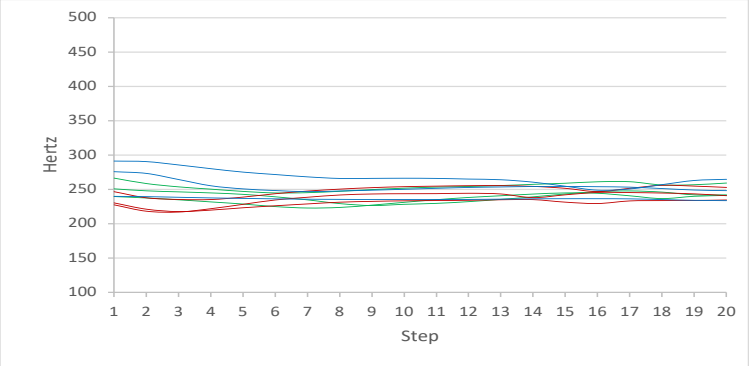
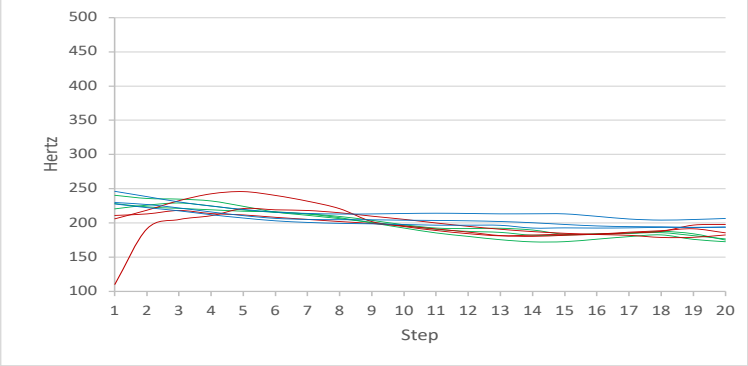
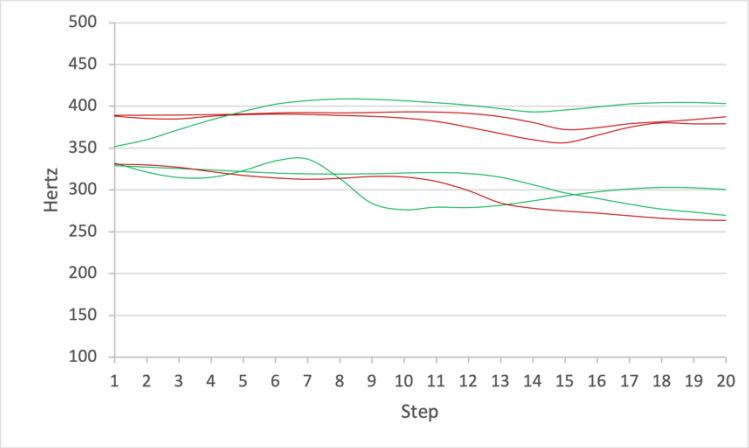


FIGURE 13: Individual utterances for low falling tone



,

FIGURE 14: Individual utterances for tone 8



The statistical results also support the eight distinctive disyllabic tones in NCG. Table 15 and 16 below show mid tone and low rising tone as distinctive tones in disyllabic words by comparing the monosyllabic mid tone and low rising tone with different tones in the first syllable of the disyllabic compounds. Results of pairwise comparison on the three pitch parameters (intercept, slope and curvature) show that regarding tonal contrast, none of the three parameters is significantly different which indicates the monosyllabic mid tone, and the monosyllabic low rising tone is both preserved in the disyllabic context as distinct tones.

TABLE 15: Results of pairwise comparison of pitch parameters for monosyllabic mid tone and the tones in disyllabic context

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t value*	*Pr* > |*t*|
Mid_mid vs.mid	intercept	-2.2703	10.8538	-0.21	0.8345
	slope	17.6938	16.6617	1.06	0.2895
	curvature	-7.2009	6.4314	-1.12	0.2641
Mid_low rising vs. mid	intercept	5.6435	10.8538	0.52	0.6036
	slope	20.5560	16.6617	1.23	0.2187
	curvature	-0.07222	6.4314	-0.01	0.9911
Falling rising_low rising vs. mid	intercept	0.1102	10.8538	0.01	0.9919
	slope	11.8708	16.6617	0.71	0.4770
	curvature	9.5480	6.4314	1.48	0.1391

Low rising_mid vs. mid	intercept	-15.9172	10.8538	-1.47	0.1440
	slope	30.3288	16.6617	1.82	0.0701
	curvature	-1.0699	6.4314	-0.17	0.8680
High rising_mid vs. mid	intercept	21.3962	10.8538	1.97	0.0500
	slope	24.4836	16.6617	1.47	0.1432
	curvature	-11.7794	6.4314	-1.83	0.0684
Mid falling_mid vs. mid	intercept	-12.2988	10.8538	-1.13	0.2585
	slope	22.8040	16.6617	1.37	0.1726
	curvature	-4.0680	6.4314	-0.63	0.5277
Mid falling_low rising vs. mid	intercept	4.5908	10.8538	0.42	0.6728
	slope	-14.9618	16.6617	-0.90	0.3702
	curvature	-5.8412	6.4314	-0.91	0.3648
Mid falling_high rising vs. mid	intercept	10.0424	10.8538	0.93	0.3559
	slope	-8.9350	16.6617	-0.54	0.5923
	curvature	7.4397	6.4314	1.16	0.2487
Mid falling_mid falling vs. mid	intercept	-7.0835	10.8538	-0.65	0.5147
	slope	21.3296	16.6617	1.28	0.2019
	curvature	12.0018	6.4314	1.87	0.0634

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

TABLE 16: Results of pairwise comparison of pitch parameters for monosyllabic low rising tone and tones in disyllabic context

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t value*	*Pr > |t|*
Falling rising_falling rising vs. low rising	intercept	0.1102	10.8538	0.01	0.9919
	slope	1.0848	16.6617	0.07	0.9482
	curvature	-10.0227	6.4314	-1.56	0.1206
Mid_falling rising vs. low rising	slope	21.2208	16.6617	1.27	0.2042
	curvature	7.3080	6.4314	1.14	0.2571
Low rising_falling rising vs. low rising	intercept	9.8115	10.8538	0.90	0.3671
	slope	18.2301	16.6617	1.09	0.2752
	curvature	8.7160	6.4314	1.36	0.1768
Low rising_low rising vs. low rising	intercept	14.3536	10.8538	1.32	0.1875
	slope	7.3933	16.6617	0.44	0.6577
	curvature	-0.8024	6.4314	-0.12	0.9008
Low rising_high rising vs. low rising	intercept	10.8146	10.8538	1.00	0.3202
	slope	18.3410	16.6617	1.10	0.2722
	curvature	9.6065	6.4314	1.49	0.1368
Low rising_mid falling vs. low rising	intercept	-7.1414	10.8538	-0.66	0.5113
	slope	-30.1534	16.6617	-1.81	0.0718
	curvature	4.9418	6.4314	0.77	0.4431

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

The statistics also found that when put as the first syllable in a disyllabic compound, some tones change into new tones that are distinctive from the monosyllabic tones. Results of pairwise comparison on the three pitch parameters (intercept, slope and curvature) display that, by comparing each of the six new tones (high tone, low tone, low falling tone, (new) mid falling tone, mid rising tone and tone 8) with the monosyllabic tones, there is at least one parameter that is significantly different enough to make the six new tones distinctive from the monosyllabic tones.

TABLE 17: Results of pairwise comparison of pitch parameters for high tone in disyllabic context and monosyllabic tones

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t value*	*Pr > |t|*
High_falling rising vs. mid	**intercept**	**134.19**	**12.1711**	**11.03**	**<.0001**
	slope	**46.0234**	**18.6797**	**2.46**	**0.0146**
	curvature	-4.8474	7.2027	-0.67	0.5017
High_falling rising vs. falling rising	**intercept**	**198.03**	**12.1711**	**16.27**	**<.0001**
	slope	-5.7535	18.6797	-0.31	0.7584
	curvature	**-53.6903**	**7.2027**	**-7.45**	**<.0001**
High_falling rising vs. low rising	**intercept**	**153.40**	**12.1711**	**12.60**	**<.0001**
	slope	**-37.8232**	**18.6797**	**-2.02**	**0.0442**
	curvature	**-21.6566**	**7.2027**	**-3.01**	**0.0030**
High_falling rising vs. high rising	**intercept**	-7.1776	12.1711	-0.59	0.5560
	slope	**-88.3516**	**18.6797**	**-4.73**	**<.0001**
	curvature	10.0211	7.2027	1.39	0.1656
High_falling rising vs. mid falling	**intercept**	**-174.16**	**12.1711**	**-14.31**	**<.0001**
	slope	**-143.41**	**18.6797**	**-7.68**	**<.0001**
	curvature	-2.4856	7.2027	-0.35	0.7304

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

TABLE 18: Results of pairwise comparison of pitch parameters for low tone in disyllabic context and monosyllabic tones

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t value*	*Pr > |t|*
Low_mid falling vs. mid	**intercept**	**-23.7631**	**10.8538**	**-2.19**	**0.0297**
	slope	**36.6369**	**16.6617**	**2.20**	**0.0290**
	curvature	0.3991	6.4314	0.06	0.9506
Low_mid falling vs. low rising	intercept	4.5630	10.8538	0.42	0.6746
	slope	**47.2097**	**16.6617**	**2.83**	**0.0051**
	curvature	**16.4101**	**6.4314**	**2.55**	**0.0114**
Low_mid falling vs. falling rising	**intercept**	**-40.0726**	**10.8538**	**-3.69**	**0.0003**
	slope	15.1400	16.6617	0.91	0.3646
	curvature	**48.4437**	**6.4314**	**7.53**	**<.0001**
Low_mid falling vs. high rising	**intercept**	**165.14**	**10.8538**	**15.21**	**<.0001**
	slope	**97.7381**	**16.6617**	**5.87**	**<.0001**
	curvature	**-15.2676**	**6.4314**	**-2.37**	**0.0185**
Low_mid falling vs. mid falling	intercept	-16.1985	10.8538	-1.49	0.1371
	slope	**-134.02**	**16.6617**	**-8.04**	**<.0001**
	curvature	-7.7322	6.4314	-1.20	0.2306

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

TABLE 19: Results of pairwise comparison of pitch parameters for low falling tone in disyllabic context and monosyllabic tones

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t value*	*Pr > |t|*
Low falling_mid vs. mid	**intercept**	**-66.3218**	**10.8538**	**-6.11**	**<.0001**
	slope	-20.4889	16.6617	-1.23	0.2202
	curvature	11.0434	6.4314	1.72	0.0874
Low falling_mid vs. falling rising	intercept	-2.4861	10.8538	-0.23	0.8191
	slope	**-72.2658**	**16.6617**	**-4.34**	**<.0001**
	curvature	**-37.7995**	**6.4314**	**-5.88**	**<.0001**
Low falling_mid vs. low rising	**intercept**	**47.1216**	**10.8538**	**4.34**	**<.0001**
	slope	**104.34**	**16.6617**	**6.26**	**<.0001**
	curvature	5.7659	6.4314	0.90	0.3710
Low falling_mid vs. high rising	**intercept**	**207.69**	**10.8538**	**19.14**	**<.0001**
	slope	**154.86**	**16.6617**	**9.29**	**<.0001**
	curvature	**-25.9119**	**6.4314**	**-4.03**	**<.0001**
Low falling_mid vs. mid falling	**intercept**	**26.3601**	**10.8538**	**2.43**	**0.0160**
	slope	**-76.8953**	**16.6617**	**-4.62**	**<.0001**
	curvature	**-18.3764**	**6.4314**	**-2.86**	**0.0047**
Low falling_high rising vs. mid	**intercept**	**-42.4405**	**10.8538**	**-3.91**	**0.0001**

	slope	3.4232	16.6617	0.21	0.8374
	curvature	7.5930	6.4314	1.18	0.2391
Low falling_high rising vs. falling rising	intercept	21.3952	10.8538	1.97	0.0500
	slope	**-48.3537**	**16.6617**	**-2.90**	**0.0041**
	curvature	**-41.2498**	**6.4314**	**-6.41**	**<.0001**
Low falling_high rising vs. low rising	**intercept**	**23.2403**	**10.8538**	**2.14**	**0.0334**
	slope	**80.4234**	**16.6617**	**4.83**	**<.0001**
	curvature	9.2162	6.4314	1.43	0.1533
Low falling_high rising vs. high rising	**intercept**	**183.81**	**10.8538**	**16.94**	**<.0001**
	slope	**130.95**	**16.6617**	**7.86**	**<.0001**
	curvature	**-22.4615**	**6.4314**	**-3.49**	**0.0006**
Low falling_high rising vs. mid_falling	intercept	2.4788	10.8538	0.23	0.8196
	slope	**-100.81**	**16.6617**	**-6.05**	**<.0001**
	curvature	**-14.9260**	**6.4314**	**-2.32**	**0.0213**
Low falling_mid falling vs. mid	**intercept**	**-58.9153**	**10.8538**	**-5.43**	**<.0001**
	slope	-0.02920	16.6617	-0.00	0.9986
	curvature	10.6634	6.4314	1.66	0.0988
Low falling_mid falling vs. falling rising	**intercept**	**-58.9153**	**10.8538**	**-5.43**	**<.0001**
	slope	**-51.8061**	**16.6617**	**-3.11**	**0.0021**
	curvature	**-38.1795**	**6.4314**	**-5.94**	**<.0001**
Low falling_mid falling vs. low rising	**intercept**	**47.1216**	**10.8538**	**4.34**	**<.0001**
	slope	**83.8758**	**16.6617**	**5.03**	**<.0001**
	curvature	6.1459	6.4314	0.96	0.3404
Low falling_mid falling vs. high rising	**intercept**	**200.29**	**10.8538**	**18.45**	**<.0001**
	slope	**134.40**	**16.6617**	**8.07**	**<.0001**
	curvature	**-25.5319**	**6.4314**	**-3.97**	**<.0001**
Low falling_mid falling vs. mid falling	intercept	18.9536	10.8538	1.75	0.0822
	slope	**-97.3550**	**16.6617**	**-5.84**	**<.0001**
	curvature	**-17.9964**	**6.4314**	**-2.80**	**0.0056**

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

TABLE 20: Results of pairwise comparison of pitch parameters for (new) mid falling tone in disyllabic context and monosyllabic tones

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t value*	*Pr > |t|*
Mid falling_falling rising vs. mid	intercept	-15.2530	10.8538	-1.41	0.1614
	slope	-32.1136	16.6617	-1.93	0.0553
	curvature	**-17.2313**	**6.4314**	**-2.68**	**0.0080**
Mid falling_falling rising vs. falling rising	**intercept**	**48.5828**	**10.8538**	**4.48**	**<.0001**
	slope	**-83.8905**	**16.6617**	**-5.03**	**<.0001**
	curvature	**-66.0741**	**6.4314**	**-10.27**	**<.0001**
	intercept	3.9472	10.8538	0.36	0.7165

Mid falling_falling rising vs. low rising	**slope**	**-115.96**	**16.6617**	**-6.96**	**<.0001**
	curvature	**-34.0405**	**6.4314**	**-5.29**	**<.0001**
Mid falling_falling rising vs. high rising	**intercept**	**-156.63**	**10.8538**	**-14.43**	**<.0001**
	slope	**-166.49**	**16.6617**	**-9.99**	**<.0001**
	curvature	-2.3628	6.4314	-0.37	0.7137
Mid falling_falling rising vs. mid falling	**intercept**	**24.7087**	**10.8538**	**2.28**	**0.0238**
	slope	**65.2706**	**16.6617**	**3.92**	**0.0001**
	curvature	-9.8983	6.4314	-1.54	0.1253

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

TABLE 21: Results of pairwise comparison of pitch parameters for mid tone in disyllabic context and monosyllabic tones

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t Value*	*Pr > |t|*
Mid rising _mid falling vs. mid	**intercept**	11.6017	10.8538	1.07	0.2863
	slope	**65.8738**	**16.6617**	**3.95**	**0.0001**
	curvature	-6.3078	6.4314	-0.98	0.3278
Mid rising _mid falling vs. falling rising	**intercept**	**75.4375**	**10.8538**	**6.95**	**<.0001**
	slope	14.0969	16.6617	0.85	0.3985
	curvature	**-55.1507**	**6.4314**	**-8.58**	**<.0001**
Mid rising _mid falling vs. low rising	**intercept**	**30.8019**	**10.8538**	**2.84**	**0.0050**
	slope	-17.9728	16.6617	-1.08	0.2820
	curvature	**-23.1170**	**6.4314**	**-3.59**	**0.0004**
Mid rising _mid falling vs. high rising	**intercept**	**-129.77**	**10.8538**	**-11.96**	**<.0001**
	slope	**-68.5012**	**16.6617**	**-4.11**	**<.0001**
	curvature	8.5607	6.4314	1.33	0.1846
Mid rising _mid falling vs. mid falling	**intercept**	**-51.5634**	**10.8538**	**-4.75**	**<.0001**
	slope	**-163.26**	**16.6617**	**-9.80**	**<.0001**
	curvature	-1.0252	6.4314	-0.16	0.8735

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

TABLE 22: Results of pairwise comparison of pitch parameters for tone 8 in disyllabic context and monosyllabic tones

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t Value*	*Pr > |t|*
Tone 8_low rising vs. mid	**intercept**	**79.1427**	**12.1711**	**6.50**	**<.0001**
	slope	-8.7736	18.6797	-0.47	0.6391
	curvature	-6.2989	7.2027	-0.87	0.3828

Tone 8_low rising vs. falling rising	**intercept**	**79.1427**	**12.1711**	**6.50**	**<.0001**
	slope	**-60.5505**	**18.6797**	**-3.24**	**0.0014**
	curvature	**-55.1417**	**7.2027**	**-7.66**	**<.0001**
Tone 8_low rising vs. low rising	**intercept**	**142.98**	**12.1711**	**11.75**	**<.0001**
	slope	**-92.6202**	**18.6797**	**-4.96**	**<.0001**
	curvature	**-23.1081**	**7.2027**	**-3.21**	**0.0015**
Tone 8_low rising vs. high_rising	**intercept**	**-62.2298**	**12.1711**	**-5.11**	**<.0001**
	slope	**-143.15**	**18.6797**	**-7.66**	**<.0001**
	curvature	8.5696	7.2027	1.19	0.2355
Tone 8_low rising vs. mid falling	**intercept**	**-119.10**	**12.1711**	**-9.79**	**<.0001**
	slope	**-88.6106**	**18.6797**	**-4.74**	**<.0001**
	curvature	-1.0342	7.2027	-0.14	0.8860

*Note: A_B represents tonal combination in the disyllabic compounds (i.e., mid_mid represents in a disyllabic compound which a mid tone is followed by a mid tone)

Moreover, the summary Table 23 (please find the full table in Appendix 2) shows that, by comparing those six new tones with each other, the results of pairwise comparison on the three pitch parameters (intercept, slope, and curvature) indicate that there is at least one petameter which is significantly different to make the six tones distinct from each other:

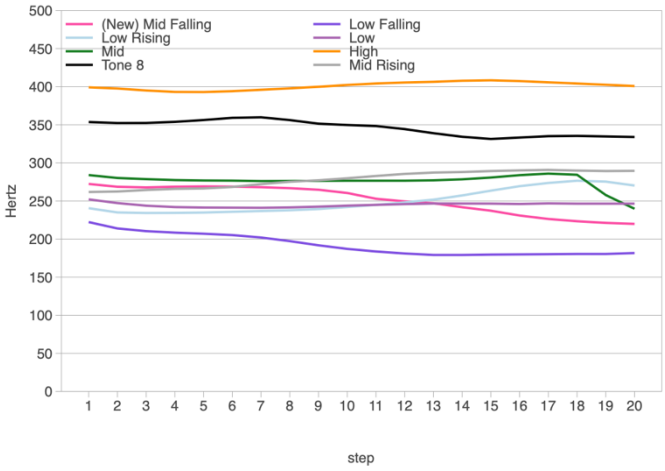
TABLE 23: Summary of the results of pairwise comparison of pitch parameters for the disyllabic tone contrasts

Tonal contrast	Intercept	Slope	Curvature
Tone 8 vs. low falling	***		*
Tone 8 vs. low	***	*	
Tone 8 vs. high	***		
Tone 8 vs. (new) mid falling	***		
Tone 8 vs. mid rising	***	**	
Low falling vs. mid	**	**	
Low falling vs. high	***	**	**
Low falling vs. mid rising	*	**	**

Low falling vs. (new) mid falling	***		***
Low vs. high	***		
Low vs. mid rising	*		
Low vs. (new) mid falling		***	*
(new) mid falling vs. mid rising	***		
(new) mid falling vs. high	***	***	
Mid rising vs. high	**	***	

Figure 15 presents the disyllabic tones plotted altogether in one graph, which helps to visualize the tones and their relative highness with each other. It also reconfirms that there are in total eight tones in the disyllabic context in NCG: high tone, low tone, low falling tone, (new) mid falling tone, mid rising tone, and tone 8.

FIGURE 15: NCG disyllabic tone contours



4.3. Tone Sandhi: A Phonetic Analysis

Some tone sandhi patterns emerged from the process of putting the monosyllabic word as the first word in the disyllabic compounds. Table 24 shows tone sandhi production across nine

types of tonal contexts by presenting both the monosyllabic one and the one after tone sandhi in the disyllabic context: a. mid falling tone becomes mid tone when followed by a non-falling rising tone; b. mid tone or falling rising tone becomes low rising tone when followed by falling rising tone; c. low rising tone or high rising tone is changed to mid tone when followed by a mid tone; d. high rising tone becomes high tone when followed by falling rising tone; e. falling rising tone is changed to low falling tone when followed by either mid falling tone, high rising tone, or mid tone; f. mid tone becomes low tone when followed by mid falling tone; g. mid falling tone is changed to (new) mid falling tone when followed by falling rising tone; h. high rising tone becomes mid rising tone when followed by mid falling tone; i. high rising tone is changed to tone 8 when followed by low rising tone.

TABLE 24: Summarized tone sandhi patterns in NCG

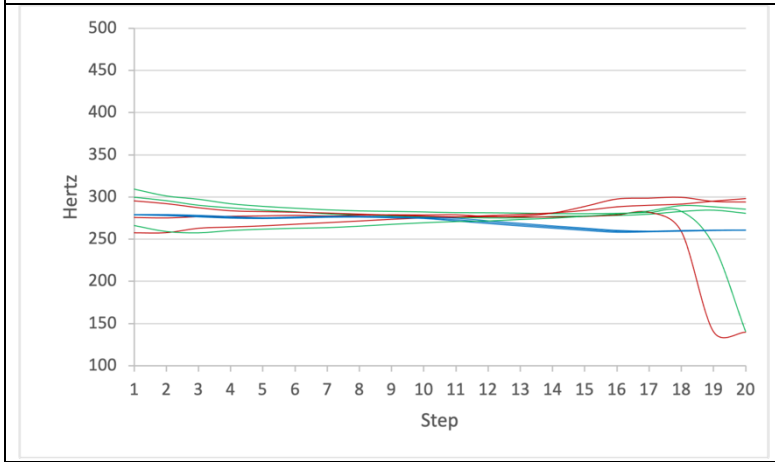
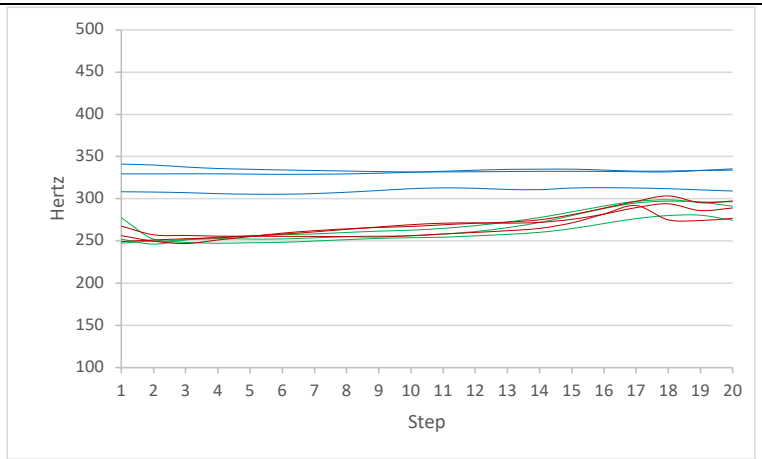
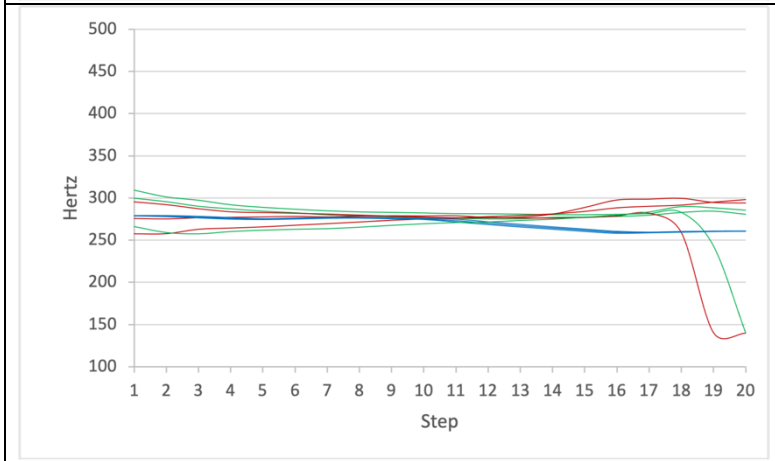
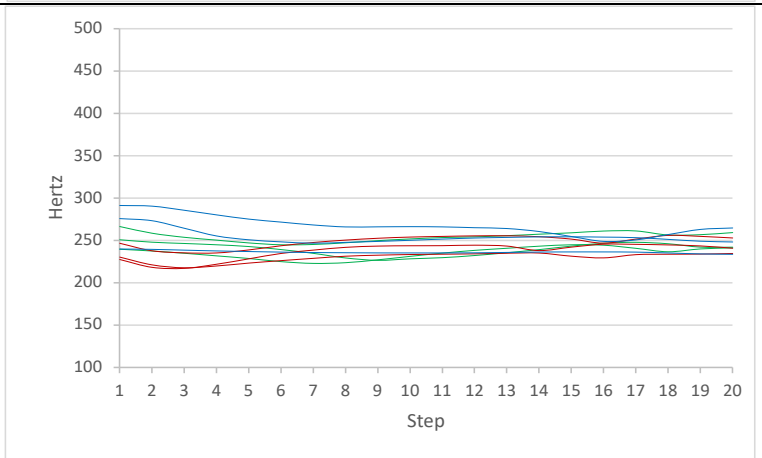
2^{nd} σ / 1^{st} σ	Mid	Falling rising	Low rising	High rising	Mid falling
Mid	$T_{σ1}$-$T_{σ2}$	low rising-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$	low-$T_{σ2}$
Falling rising	low falling-$T_{σ2}$	low rising-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$	low falling-$T_{σ2}$	low falling-$T_{σ2}$
Low rising	mid-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$	$T_{σ1}$-$T_{σ2}$
High rising	mid-$T_{σ2}$	high-$T_{σ2}$	Tone 8-$T_{σ2}$		mid rising-$T_{σ2}$
Mid falling	mid-$T_{σ2}$	(new) mid falling-$T_{σ2}$	mid-$T_{σ2}$	mid-$T_{σ2}$	mid-$T_{σ2}$

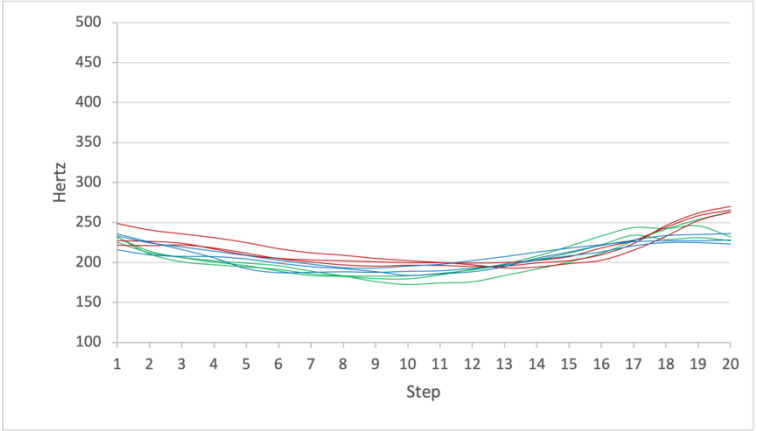
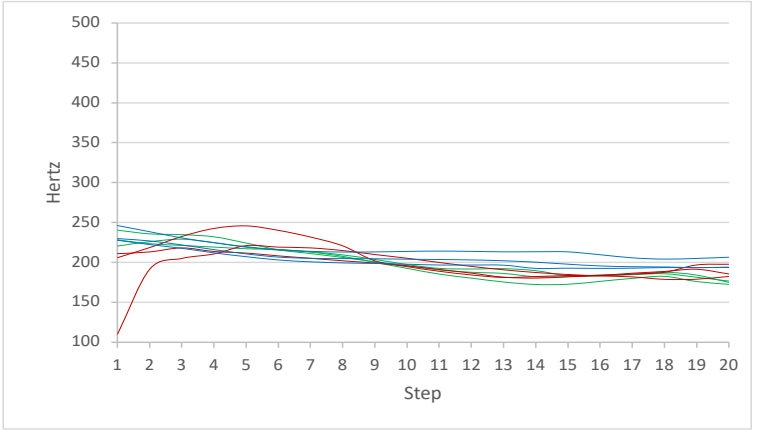
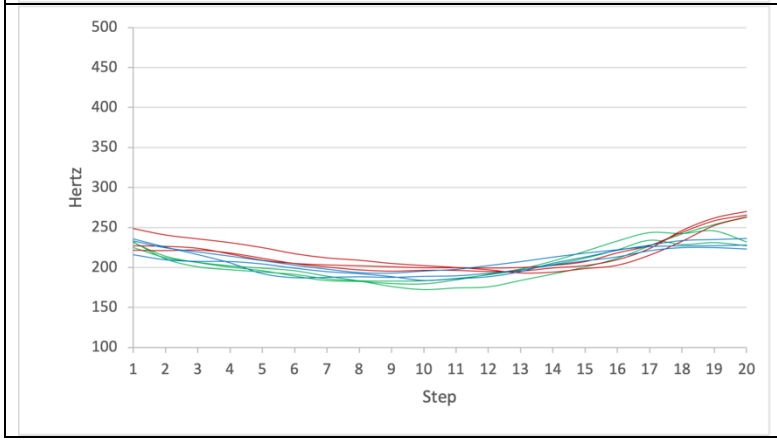
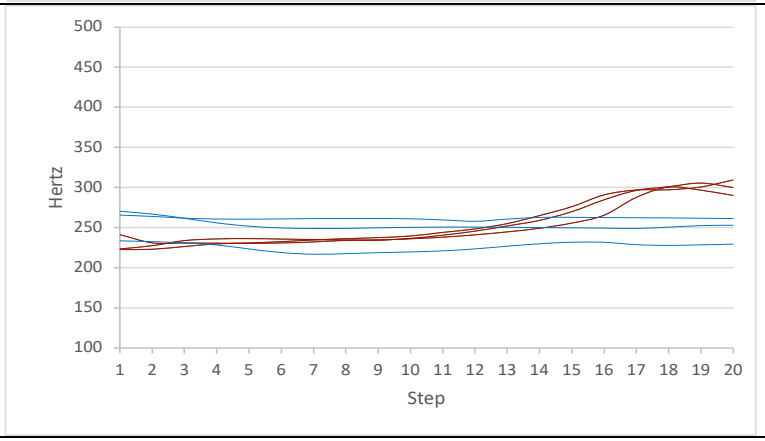
The sandhi patterns in NCG are not incidental, some of them can be found parallel on Mandarin tone sandhi. In Mandarin, there are two famous tone sandhis: full sandhi and half sandhi. In the full sandhi context, the falling rising tone of the first syllable is changed to a rising tone, while it is changed to a low falling tone in the three half sandhi contexts (that is, when the

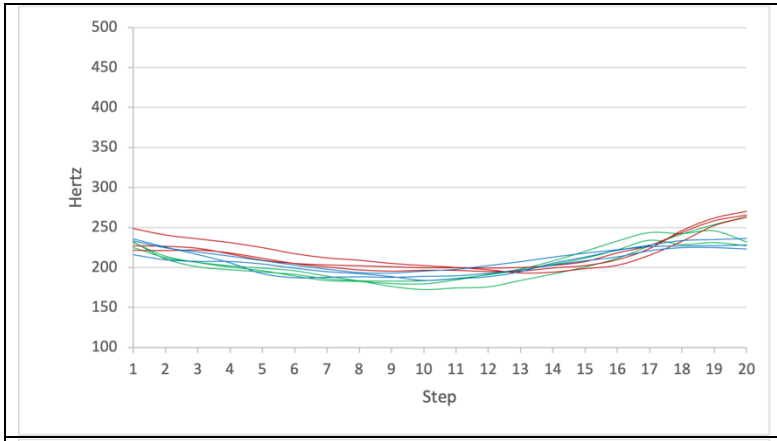
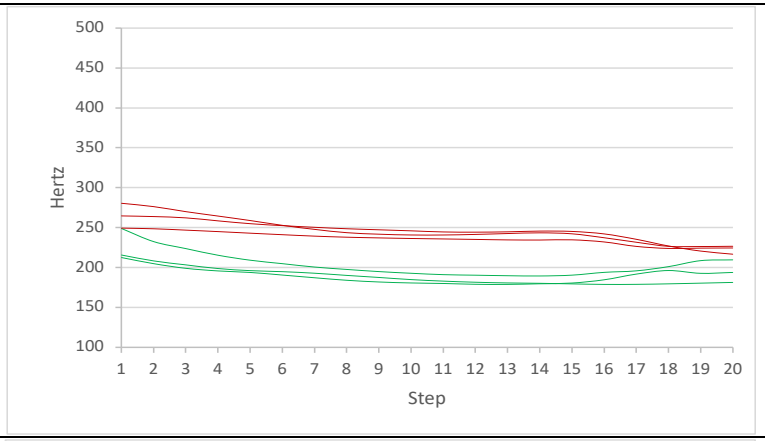
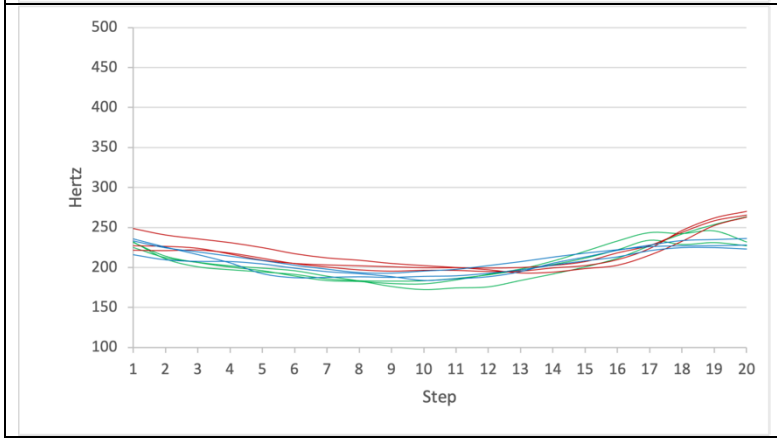
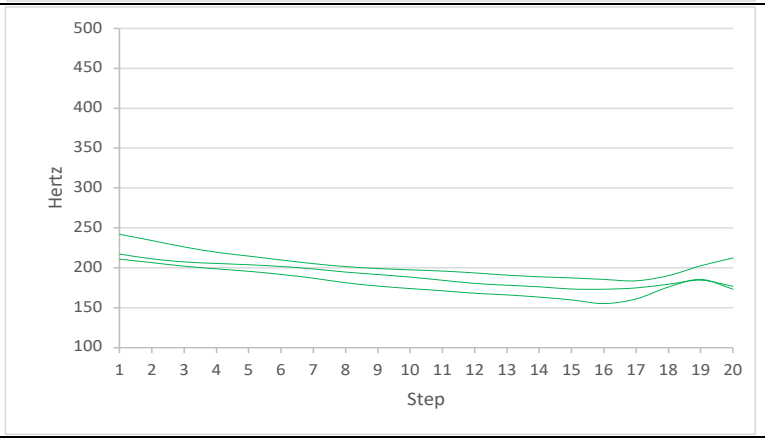
falling rising tone is preceded by either high tone, high falling tone and rising tone). This pattern can be generally observed in NCG as well, as NCG has falling rising tone which is indistinguishable from that in Mandarin: in NCG, falling rising tone is changed to low rising tone when followed by falling rising tone, in most other cases (except when it is followed by low rising tone), it is changed to low falling tone. Some other general patterns can be noted as well: mid falling tone often changed to mid tone in the disyllabic context, except when it's followed by a falling rising tone (then it is changed to the (new) mid falling tone); low rising tone only goes through tone sandhi when it is followed by a mid tone.

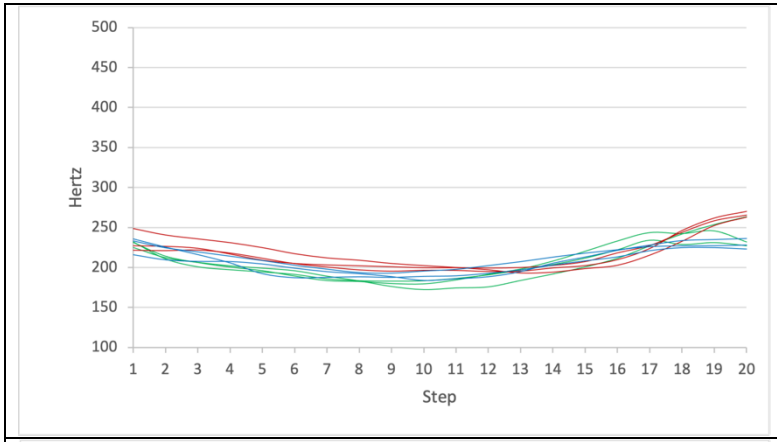
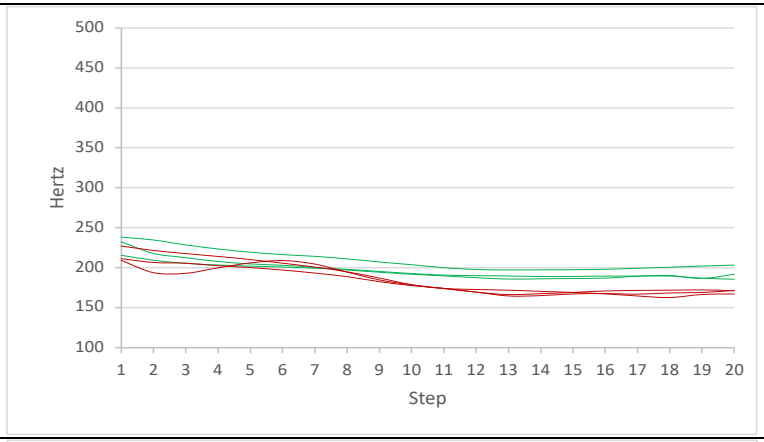
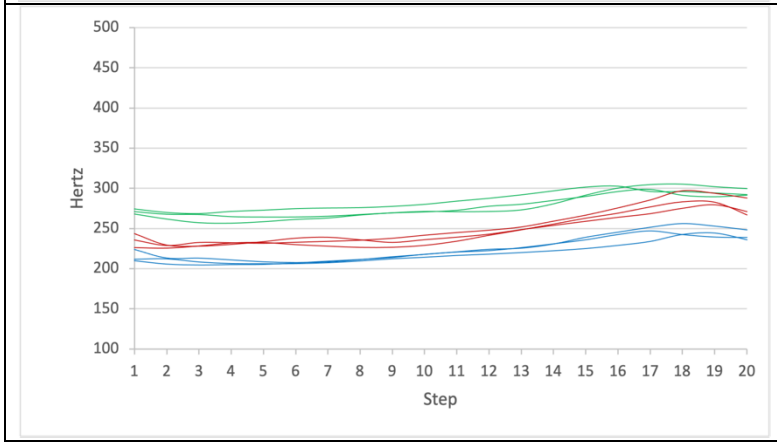
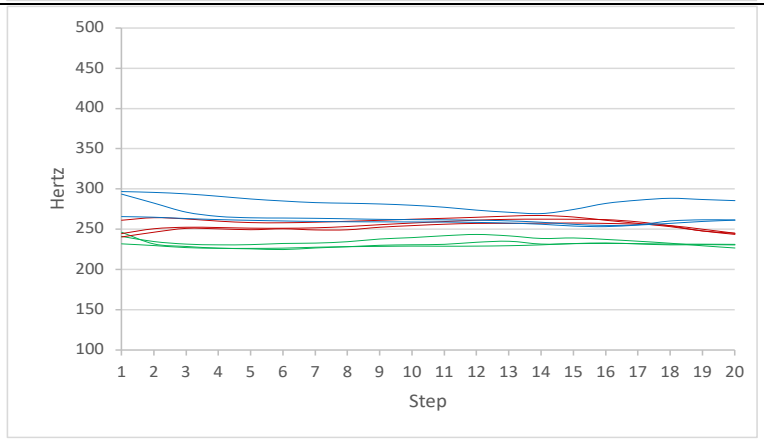
Some degree of neutralization can be observed here as we see some tones lose their contrastiveness and thus are neutralized in the tone sandhi process. For example, mid falling tone is neutralized to mid tone when followed by a non-falling rising tone; high rising tone is neutralized to high tone when followed by falling rising tone; low rising tone or high rising tone is neutralized to mid tone when followed by a mid tone.

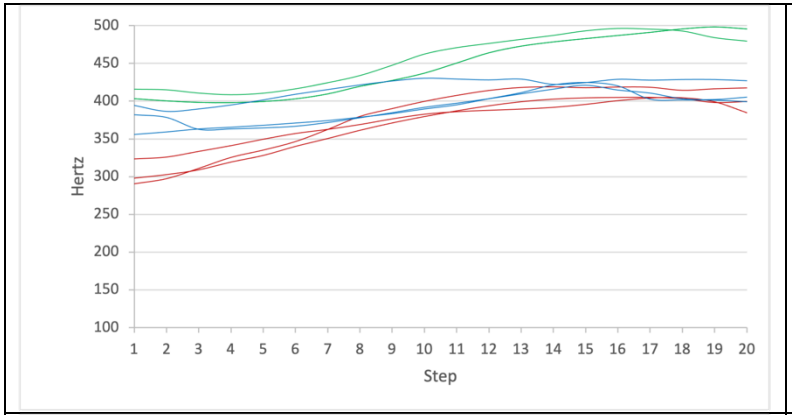
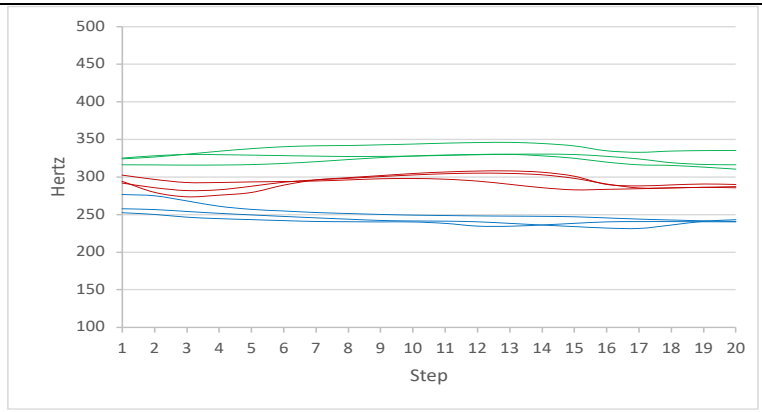
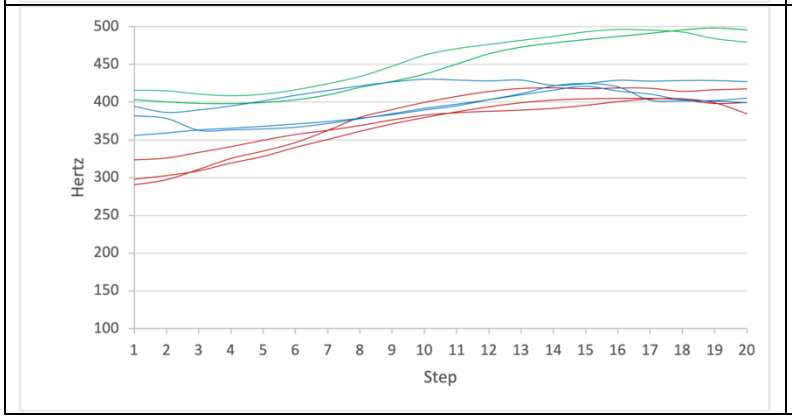
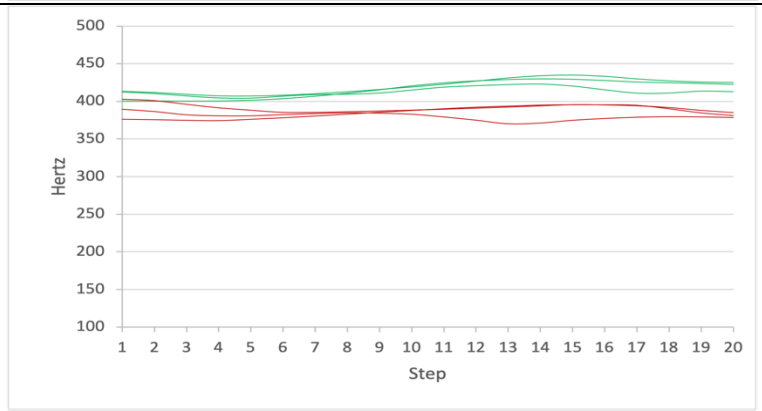
FIGURE 16: Pitch contours of tone sandhi in NCG

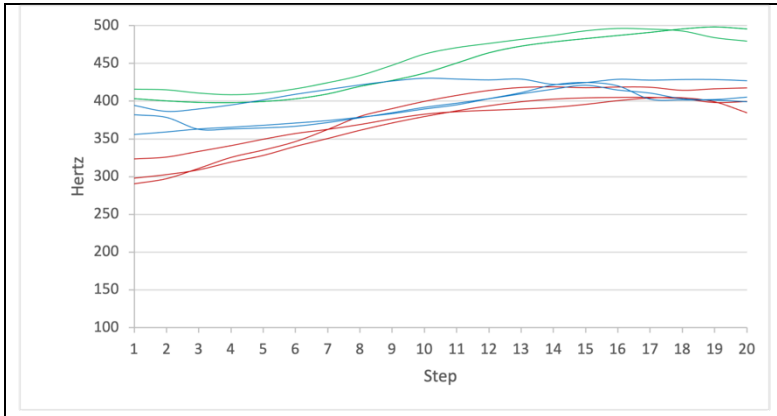
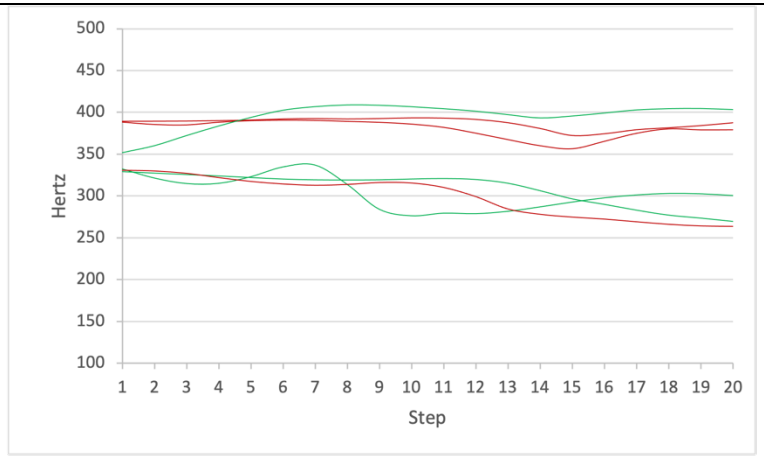
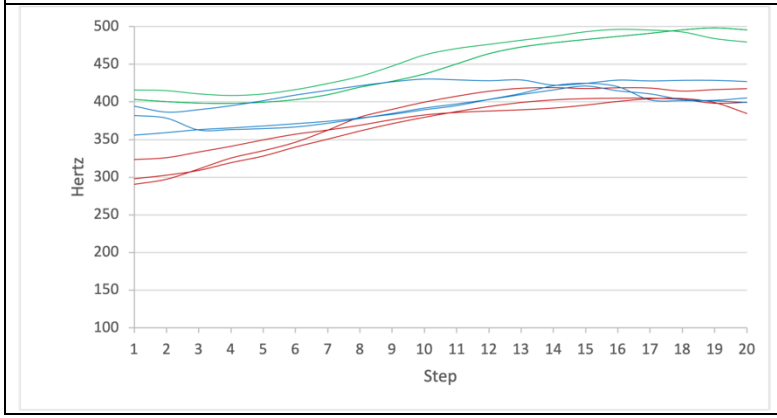
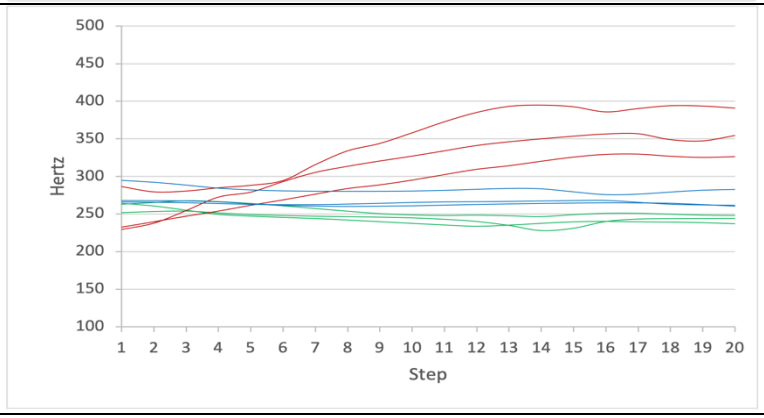
Monosyllabic tone	Disyllabic tone	Tone sandhi pattern
		Mid→ low rising/__ falling rising
		Mid→low/_mid falling

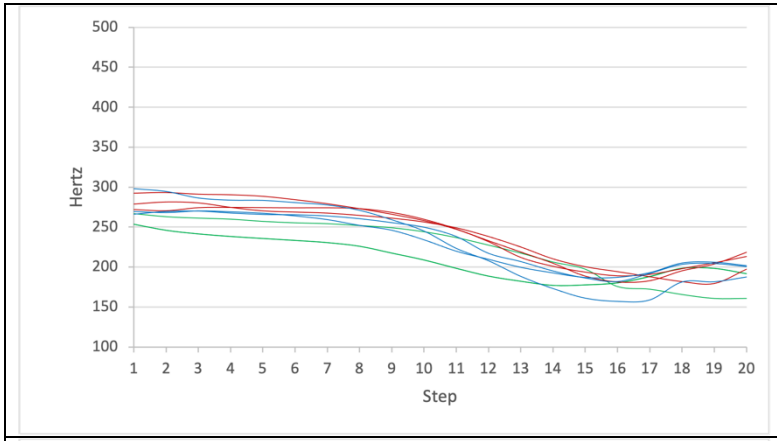
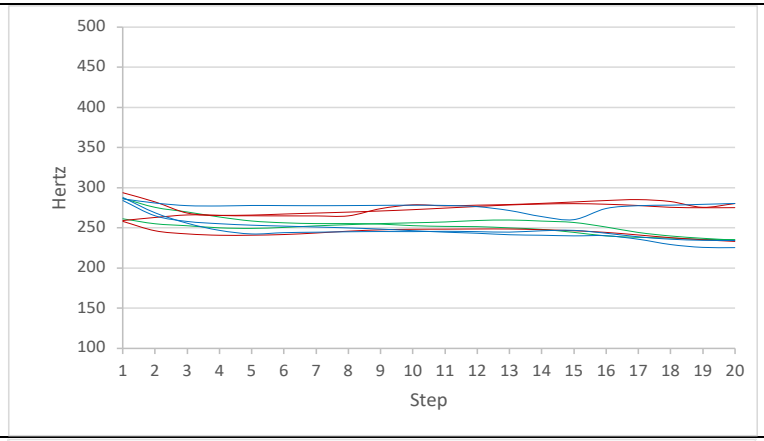
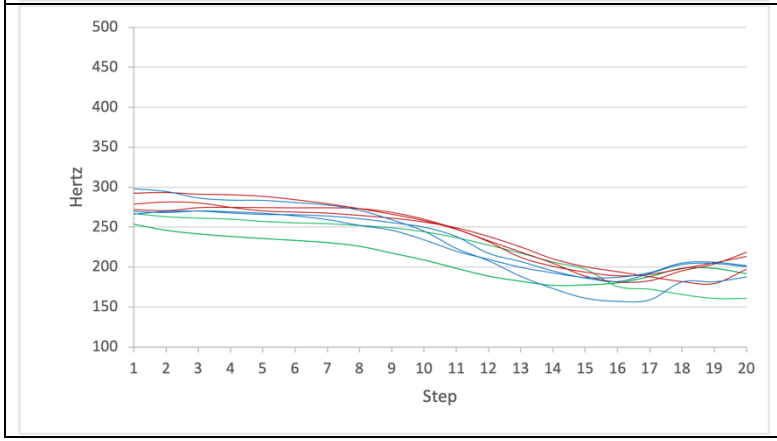
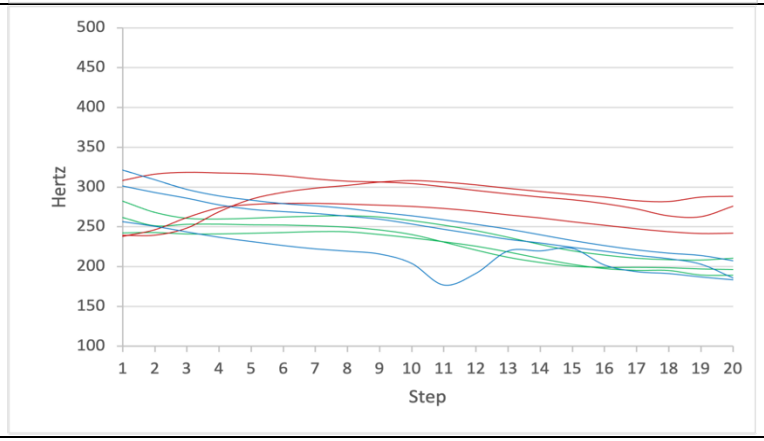
		Falling rising → low falling/ __mid
		Falling rising → low rising /__ falling rising

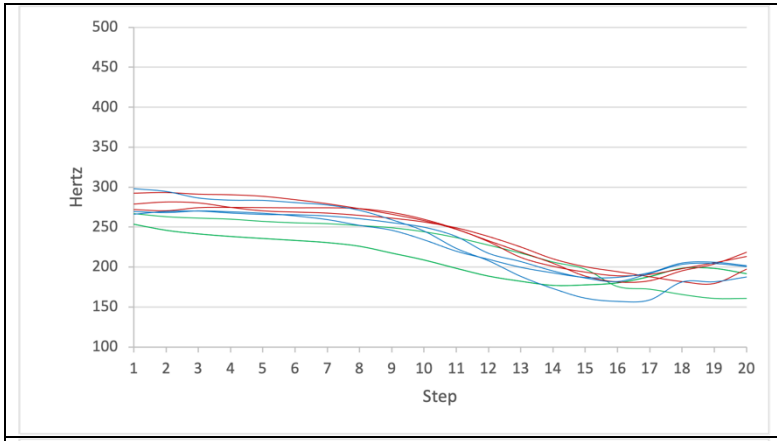
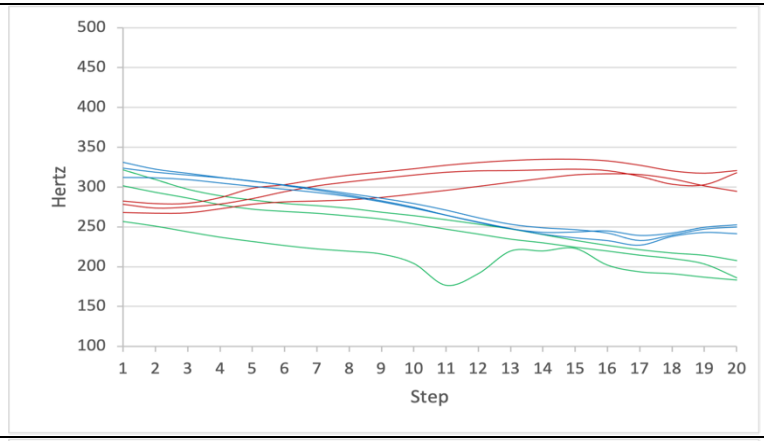
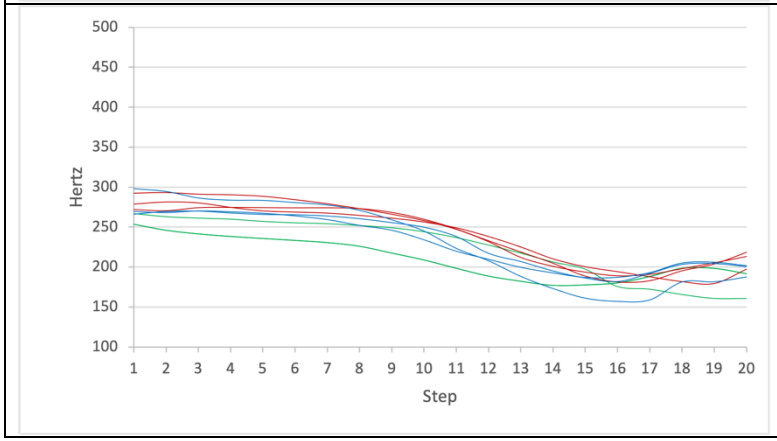
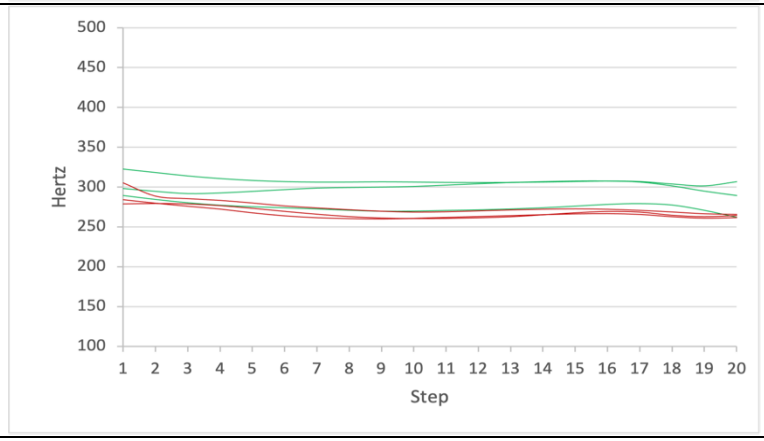
		Falling rising→ mid/__low rising
		Falling rising → low falling /__ high rising

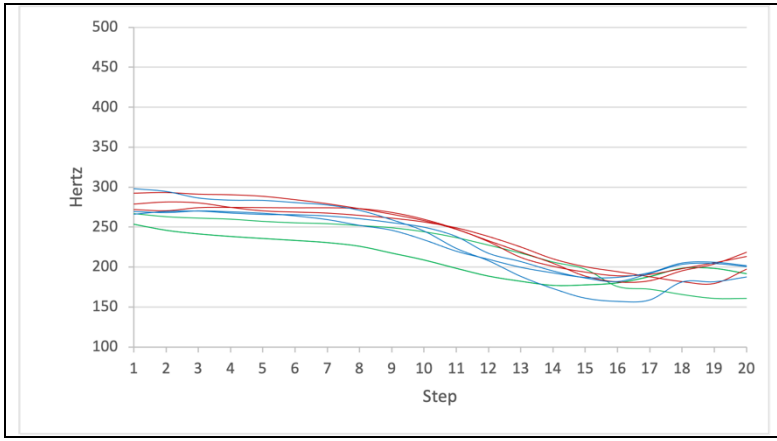
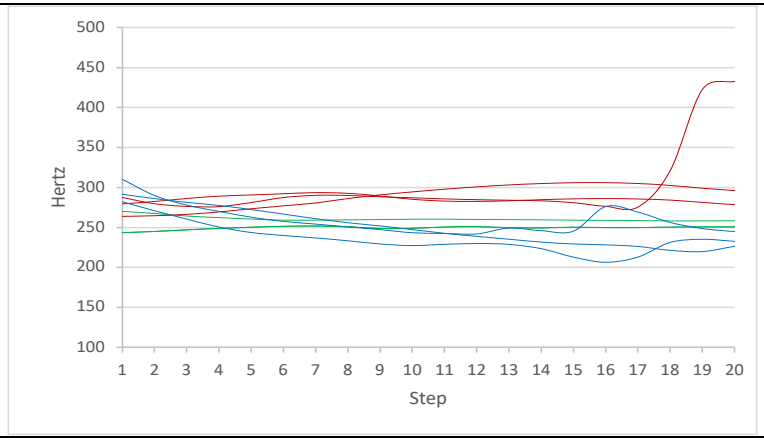
		Falling rising → low falling /__ mid falling
		Low rising → mid /__mid

		High rising → mid /__mid
		High rising → high/__ falling rising

		High rising →tone 8 /__low rising
		High rising →mid rising/__mid falling

		Mid falling → mid/ __mid
		mid falling → (new) mid falling/_falling rising

		Mid falling→ mid/__ low rising
		Mid falling → mid/__ high rising

		Mid falling → mid/ __mid falling

*Note: the three sets of monosyllabic words were color-coded: [ka/k^{h}a]-green, [ɲa/ɲɛ/ŋa]-red, [ɸa]-blue

Visual inspection of Figure 16 suggests that utterances are not always behaving consistently in the tone sandhi production: for example, in the case where mid tone becomes low rising when followed by falling rising tone, [ɸa] utterances behave more mid-tone-like, showing a flatter pitch contour than the other two sets. In the case where falling rising tone becomes low rising tone before falling rising tone, [ɸa] utterances also show a less steep shape which resembles a mid tone while [ɲa/ɲɛ/ŋa] set displays a low rising trend. [ka/kʰa] & [ɸa] display less mid-like but more mid falling pitch trend in the case where mid falling tone is changed to mid tone when followed by low rising tone. Figure 16 also gives us new direction for analyzing the two complicated sandhi tones: tone 8 & (new) mid falling tone. By looking at those tones utterance by utterance, it looks like they are specific to one particular tone combination (high rising becomes tone 8 when followed by low rising; mid falling becomes (new) mid falling when followed by falling rising), and it may be possible that they are combinations of the tones that have been defined rather than new tones: for the (new) mid falling tone, it consists of a mid tone presented by [ɲa/ɲɛ/ŋa], and a mid falling tone as displayed by [ka/kʰa] & [ɸa]. For tone 8, [ɲa/ɲɛ/ŋa] shows a mid tone trend while [ka/kʰa] shows a mid rising trend. The inconsistency within utterances may be due to mispronunciations or the indications of some underlying phonological patterns that can be explained with more data in the future. Also, what we have categorized as “tone 8” in the previous section is actually consisting of two “old” tones: mid tone and mid rising tone (more detail in 4.3).

CHAPTER 5: CONCLUSION

This study examined tones and tone sandhi in Nanchang Gan. The results show that there are five monosyllabic tones in Nanchang Gan, which is consistent with the proposal from the previous studies. However, our findings disagree with some of the categories of the five tones. based on my data, I argue that the five tones should be categorized as: mid tone, falling rising tone, low rising tone, high rising tone and mid falling tone. The analysis of disyllabic tones on the first syllable of the disyllabic compounds shows that there are disyllabic eight tones, among which mid tone and low rising tone are preserved from the monosyllabic tones, and there are six new tones emerged: high tone, low tone, low falling tone, (new) mid falling tone, mid rising tone and tone 8. By looking closely at the behavior of each utterance, it is found that some tones show more variability than others, which may be the interest to future investigation. Nine tone sandhis can be observed from the production, some of which can be referred back to the typical tone sandhis in Mandarin, which in turn reconfirms the legitimacy of current findings.

For future study, one would be expected to expand the data sample, controlling variables more rigorously, and also consider other possible factors regarding tone production, such as speaking rate and voice quality. I hope this is not an endpoint for the documentation of Nanchang Gan, as a language of my hometown, I truly sense the vulnerability and uniqueness of this language. On one hand, this study serves as the phonological documentation work of Nanchang Gan. On the other hand, it offers a foundation for possible phonological research of the language.

APPENDICES

Appendix A:

(A.1): Results of pairwise comparison of pitch parameters for the monosyllabic tone contrasts

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t Value*	*Pr > |t|*
mid vs. falling rising	**intercept**	**63.84**	**9.80**	**6.51**	**<.0001**
	slope	**-51.78**	**17.60**	**-2.94**	**0.0054**
	curvature	**-48.84**	**7.83**	**-6.24**	**<.0001**
mid vs. low rising	intercept	19.20	9.80	1.96	0.0572
	slope	**-83.85**	**17.60**	**-4.76**	**<.0001**
	curvature	**-16.81**	**7.83**	**-2.15**	**0.0380**
mid vs. high rising	**intercept**	**-141.4**	**9.80**	**-14.42**	**<.0001**
	slope	**-134.4**	**17.60**	**-7.63**	**<.0001**
	curvature	14.87	7.83	1.90	0.0649
mid vs. mid falling	**intercept**	**39.96**	**9.80**	**4.08**	**0.0002**
	slope	**97.38**	**17.60**	**5.53**	**<.0001**
	curvature	7.33	7.83	0.94	0.3548
Falling rising vs. low rising	**intercept**	**-44.64**	**9.80**	**-4.55**	**<.0001**
	slope	-32.07	17.60	-1.82	0.0760
	curvature	**32.03**	**7.83**	**4.09**	**0.0002**
Falling rising vs. high rising	**intercept**	**-205.2**	**9.80**	**-20.93**	**<.0001**
	slope	**-82.60**	**17.60**	**-4.69**	**<.0001**
	curvature	**63.71**	**7.83**	**8.13**	**<.0001**

Falling rising vs. mid falling	**intercept**	**-23.87**	**9.80**	**-2.44**	**0.0194**
	slope	**149.16**	**17.60**	**8.47**	**<.0001**
	curvature	**56.18**	**7.83**	**7.17**	**<.0001**
Low rising vs. high rising	**intercept**	**-160.6**	**9.80**	**-16.38**	**<.0001**
	slope	**-50.53**	**17.60**	**-2.87**	**0.0065**
	curvature	**31.68**	**7.83**	**4.04**	**0.0002**
Low rising vs. mid falling	**intercept**	**20.76**	**9.80**	**2.12**	**0.0405**
	slope	**181.23**	**17.60**	**10.30**	**<.0001**
	curvature	**24.14**	**7.83**	**3.08**	**0.0037**
High rising vs. mid falling	**intercept**	**181.33**	**9.80**	**18.50**	**<.0001**
	slope	**231.76**	**17.60**	**13.17**	**<.0001**
	curvature	-7.54	7.83	-0.96	0.3418

*Note: Values and tonal contrasts that are significantly different (p<.05) are bolded

(A.2) Results of pairwise comparison of pitch parameters for the disyllabic tone contrasts

Tonal contrast	Pitch parameter	*Estimate*	*SE*	*t Value*	*Pr > |t|*
Tone 8 vs. low falling	**intercept**	**138.06**	**12.1711**	**11.34**	**<.0001**
	slope	-8.7444	18.6797	-0.47	0.6402
	curvature	**-16.9622**	**7.2027**	**-2.35**	**0.0194**
Tone 8 vs. low	**intercept**	**102.91**	**12.1711**	**8.45**	**<.0001**
	slope	**-45.4104**	**18.6797**	**-2.43**	**0.0159**
	curvature	-6.6980	7.2027	-0.93	0.3535
Tone 8 vs. high	**intercept**	**-55.0522**	**13.2932**	**-4.14**	**<.0001**
	slope	34.1526	18.6797	1.83	0.0689
	curvature	-1.4514	7.8768	-0.18	0.8540
Tone 8 vs. (new) mid falling	**intercept**	**-94.3957**	**12.1711**	**-7.76**	**<.0001**
	slope	-23.3400	18.6797	-1.25	0.2129
	curvature	-10.9324	7.2027	-1.52	0.1306
Tone 8 vs. mid rising	**intercept**	**-67.5410**	**12.1711**	**-5.55**	**<.0001**

	slope	**54.0030**	**16.6617**	**3.24**	**0.0014**
	curvature	-0.00894	7.2027	-0.00	0.9990
Low falling vs. mid	**intercept**	**-35.1521**	**10.8538**	**-3.24**	**0.0014**
	slope	**-36.6661**	**16.6617**	**-2.20**	**0.0289**
	curvature	10.2642	6.4314	1.60	0.1120
Low falling vs. high	**intercept**	**193.11**	**12.1711**	**15.87**	**<.0001**
	slope	**46.0526**	**18.6797**	**2.47**	**0.0145**
	curvature	**-15.5108**	**7.2027**	**-2.15**	**0.0324**
Low falling vs. mid rising	**intercept**	**70.5170**	**10.8538**	**6.50**	**<.0001**
	slope	**65.9030**	**16.6617**	**3.96**	**0.0001**
	curvature	**-16.9712**	**6.4314**	**-2.64**	**0.0089**
Low falling vs. (new) mid falling	**intercept**	**43.6623**	**10.8538**	**4.02**	**<.0001**
	slope	-32.0844	16.6617	-1.93	0.0555
	curvature	**-27.8946**	**6.4314**	**-4.34**	**<.0001**
Low vs. high	**intercept**	**157.96**	**12.1711**	**12.98**	**<.0001**
	slope	9.3865	18.6797	0.50	0.6158
	curvature	-5.2466	7.2027	-0.73	0.4672
Low vs. mid rising	**intercept**	**35.3649**	**10.8538**	**3.26**	**0.0013**
	slope	29.2369	16.6617	1.75	0.0808
	curvature	-6.7069	6.4314	-1.04	0.2982
Low vs. (new) mid falling	intercept	8.5102	10.8538	0.78	0.4339
	slope	**-68.7504**	**16.6617**	**-4.13**	**<.0001**
	curvature	**-17.6304**	**6.4314**	**-2.74**	**0.0066**
(new) mid falling vs. mid rising	**intercept**	**-122.59**	**12.1711**	**-10.07**	**<.0001**
	slope	19.8504	18.6797	1.06	0.2892
	curvature	-1.4604	7.2027	-0.20	0.8395
(new) mid falling vs. high	**intercept**	**-149.45**	**12.1711**	**-12.28**	**<.0001**
	slope	**-78.1370**	**18.6797**	**-4.18**	**<.0001**
	curvature	-12.3839	7.2027	-1.72	0.0870
Mid rising vs. high	**intercept**	**-26.8547**	**10.8538**	**-2.47**	**0.0141**
	slope	**-97.9874**	**16.6617**	**-5.88**	**<.0001**
	curvature	-10.9235	6.4314	-1.70	0.0909

REFERENCES

Bao, Z. 1992. Toward a Typology of Tone Sandhi in Proceedings of the Eighteenth Annual Meeting of the Berkeley Linguistics Society: Special Session on The Typology of Tone Languages (1992) pp. 1-12.

Chao Y R (1968). A grammar of spoken Chinese. Berkeley & Los Angeles: University of California Press.

Gordon, R. G., Grimes, B. F., & Summer Institute of Linguistics. 2005. Ethnologue: Languages of the world. Dallas, Tex: SIL International.

Li, C.; & Thompson, S.A., Mandarin Chinese: A Functional Reference Grammar, University of California Press, 1981, p. 46.

Chen, M. 1991. An Overview of Tone Sandhi Phenomena Across Chinese Dialects. Journal of Chinese Linguistics Monograph Series, (3), 111-156. Retrieved from www.jstor.org/stable/23827037

Deng, J., & Fulop, S. 2016. Interaction between aspiration and tonal pitch in Weihai Chinese. Journal of the Acoustical Society of America. 139. 2221-2221. 10.1121/1.4950657.

Fisher, L.L. 2013. Sgaw Karen as spoken by a member of the local North Carolina Karen community: A phonetic analysis and phonemic description. Chapel Hill: University of North Carolina MA.

Haspelmath, M., & Sims, A.D. 2010. Understanding morphology. London: Hodder Education.

Language Atlas of China, by Stephen Adolphe Wurm, Rong Li, Theo Baumann and Mei W. Lee, Longman, 1987, ISBN 978-962-359-085-3.

Liu, J. 2010, 'Durational Properties of Lexical Stress and Grammatical Stress in Nanchang Chinese and Their Implications for Tonal Contrasts', Master thesis, University of Kansas, Lawrence.

Liu, Jocelyn Su-Fung. 1987. Tone sandhi in the Chinese dialects. PhD dissertation, UT Austin.

McCarthy, J. 2007. Hidden generalizations: phonological opacity in Optimality Theory. Equinox, London.

R.L. Trask, A Dictionary of Phonetics and Phonology, Routledge. 2004. Entry for "toneme".

SAS Institute Inc. 2015. SAS/STAT® 14.1 User's Guide. Cary, NC: SAS Institute Inc.

Sun, Y. 2007, 'Jiangxi Gan Fangyan Yuyin Yanjiu'. Beijing, China: Language & Culture

Press

Wright, M. 1983. A Metrical Approach to Tone Sandhi in Chinese Dialects.

Wurm, S.A., & Baumann, T. & Lee, M.W. & Chung-kuo she hui k`o hsueh yuan. & Australian National University. Research School of Pacific Studies. Department of Linguistics. & Australian Academy of the Humanities. (1988). Language atlas of China.

Yan, M. M. (2006). Introduction to Chinese dialectology. München: LINCOM Europa.

Yip, M. 2009. The tonal phonology of Chinese.

Yuan, J. 1989. Hànyǔ fāngyán gàiyào (汉语方言概要) [An introduction to Chinese dialects]. Beijing, China: Wénzì gǎigé chūbǎnshè.

Yip, M. 2002. Tone. Cambridge: Cambridge University Press. ISBN 9780521774451.

Zhang, J. 2007. A directional asymmetry in Chinese tone sandhi systems. Journal of East Asian Linguistics 16.4: 259-302.

Zhang, J. 2019. Speakers Treat Transparent and Opaque Alternation Patterns Differently — Evidence from Chinese Tone Sandhi. In Proceedings of the 36th West Coast Conference on Formal Linguistics, ed. Richard Stockwell et al., 22-40. Somerville, MA: Cascadilla Proceedings Project. www.lingref.com, document #3442.

Zhang, J., & Lai, Y. 2010. Testing the role of phonetic knowledge in Mandarin tone sandhi. *Phonology*, *27*(1), 153–201. https://doi.org/10.1017/s0952675710000060